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POPULAR GUIDE
to
The Geological Collections
in
The Indian Museum, Calcutta.

No. 5.—ECONOMIC MINERAL PRODUCTS,
By F. R. MALLET, F.G.S.,
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GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE.
Calcutta, December 1883.



PREFACE.

THE collection of economic mineral products is contained in cases 167 to 194 and 81 to 136, which occupy the recesses on the southern, and half of the northern, side of the ground floor, northern gallery (see plan annexed).

The collection is divided into sections (a list of which is given in the following table of contents), in accordance with the uses to which the raw products are put, or with the metals, and other elements, on the presence of which the value of the crude materials in most cases depends. The sections again are divided into 'Foreign' and 'Indian' sub-sections. In the former are arranged, as far as the present extent of the collections admit, standard series of the chief materials used in each branch of art, and in some cases specimens illustrative of manufacturing processes. Under 'materials for glass-making,' for instance, may be seen samples of the materials actually used in some of the chief glass-factories in England, and specimens illustrating the different operations in the manufacture of 'sheet' and 'crown' glass. Under 'copper,' again, are arranged, *1stly*, a standard series of all the important ores of copper; *2ndly*, a series of specimens, from works at Swansea, illustrating the English process of copper-smelting; and *3rdly*, samples of pigments having a cupreous base.¹ In the Indian sub-sections, the materials are grouped according to provinces so

¹ Pigments might have been grouped together in a section by themselves, but on the whole it is perhaps preferable to group them according to the metal to which they chiefly owe their color,—chrome pigments under chromium, cupreous pigments under copper, &c.

that (in as far as they are represented in the collection) the mineral products of any particular kind, and occurring in any particular province, may be seen at a glance. Under iron, for instance, the ores of Burma are placed together ; then follow in consecutive order those of Assam, Bengal, the North-Western Provinces, the Punjab, &c. In some instances series of specimens are included in the collection illustrating native methods of working, such as the manufacture of wootz steel, the dressing and smelting of copper ore, &c.

At the present time, however, both the Foreign and Indian collections leave much to be desired, some sections in both being very imperfectly represented. The difficulties in filling up such *lacunæ*, in the Indian portion especially, are by no means small. In Europe, mines, quarries, metallurgical and chemical works, &c., are generally under the direction of trained and intelligent men, who, in many cases at least, are glad to aid important public institutions, by the supply of illustrative series of specimens. Here the corresponding industries, in as far as they exist at all, are (with few important exceptions beyond coal) in the hands of men often amongst the poorest and most hardly worked of the community, who are far too ignorant to understand the meaning or requirements of a museum, and often too suspicious to willingly afford much information. To obtain really good illustrative samples of mineral or metallurgical products, &c., almost necessitates the presence on the spot of some one with a competent knowledge of the subject, and such men in India are few and far between. With the exception just noted there are few mineral industries under skilled supervision ; hence there are but few experts whose aid can be invoked, and the economic collection must be

gradually and slowly improved, as opportunity offers, by the labours of the Geological Survey and of a few zealous friends of science scattered over India here and there.

It may be well, perhaps, to remark that the following pages are intended merely for what the title page indicates—a guide to the economic collections in the museum. They do not profess to give a complete, although brief, account of the mineral resources of India, such mineral products as are not represented by specimens being in most cases passed over in silence. It is hoped that this guide may be of service to visitors to the museum, but those who wish for a full account of what is known concerning the resources of the Empire should consult Mr. V. Ball's volume on the economic geology of India,¹ where also complete references will be found to the original sources of information.

In preparing this guide, a large number of works have been consulted, but it would scarcely serve any useful purpose to give a detailed list of them. With reference to the Indian portion, the volume just quoted has held a foremost place.

The term 'Indian' is used with some latitude, specimens from countries immediately bordering on India, and in more or less intimate communication with it, being included in the Indian sub-sections. Statistical figures are given in round numbers. The heavy figures within brackets—*e.g.*, **Granite (167)**—indicate the numbers of the cases containing the specimens alluded to.

From an economic point of view, gems might be included in the collection here described, but as it has been found preferable to include them in the systematic collection of minerals, visitors are refer-

¹ Manual of the Geology of India, Part III, Economic Geology, 1881.

red, in this connection, to No. 2 of the museum guides, or to the catalogue of the mineral collection.¹

¹ *Vide* diamond, case 1; sapphire, case 7; spinel, case 8; chrysoberyl, case 9; quartz, in some of its varieties, cases 11 and 12; opal, case 13; hiddenite, case 14; beryl, emerald, chrysolite, garnet, case 16; zircon, case 17; iolite, case 18; some varieties of felspar, case 20; rubellite, case 21; topaz, case 22; turquoise, case 28; amber, case 34.

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N.B.—The heavy figures within brackets,—*e.g.* **Granite (167)**—indicate the numbers of the cases containing the specimens alluded to.



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BUILDING AND ORNAMENTAL STONES.

FOREIGN.

These are arranged on nearly the same system as that adopted by PROFESSOR E. HULL in his *Treatise on the Building and Ornamental Stones of Great Britain and Foreign Countries*. The principal sub-divisions are—

GRANITE AND GRANITOID ROCKS.
SERPENTINOUS AND ALLIED ROCKS.
VOLCANIC ROCKS.
LIMESTONES.
SANDSTONES AND ALLIED ROCKS.
SLATES.
THE RARER ORNAMENTAL STONES.

Granite (167).

Granite is a plutonic, crystalline rock, composed of quartz, felspar and mica. The intermixture of these different minerals gives the rock its mottled appearance. Owing to its durability, when well chosen, and its handsome appearance, both as a building stone and for finer purposes, granite is much sought after. Some of the more important localities from which it is obtained in the

British Islands are Aberdeenshire (I67), Cornwall, and the neighbourhood of Kingstown in Ireland. The pedestals of most of the statues in Calcutta are fine examples of British granite.

Serpentine, &c. (I67).

This rock is a hydrous silicate of magnesia, of metamorphic origin. The principal varieties, from an economic point of view, are :—

Noble, or precious, serpentine (I67), which is translucent and of a rich oil-green color.

Common serpentine (I67), the color of which is generally some shade of green, but sometimes reddish, or nearly black.

Ophiolite (from *οφις* a snake, in allusion to the diversity of color), or *verd-antique* marble (I67), a mixture of serpentine and limestone.

Serpentine is not well adapted for out-door use in architecture, on account of its liability to superficial alteration from atmospheric influences. For internal decorative purposes, however, it is in great request. Precious serpentine is largely used for vases and other ornamental articles. Owing to its softness it (as well as the common variety) admits of being easily sawn, and can be turned in a lathe, while at the same time it is susceptible of a high polish. The chief localities in which serpentine is worked in the British Islands are the Lizard in Cornwall (I67), and Connemara in the West of Ireland (I67).¹

Steatite, or soap-stone (so called from its softness and greasy feel), is a rock (I67) allied to serpentine. It is used for fire-stones in stoves and fire-places, for gas-jets, and for some other purposes.²

Volcanic rocks (I67).

Under this head are included such basaltic, dioritic, trachytic and other volcanic products as are suitable for building, &c. As examples the trachydolerite lava of Volvic (I67) in Auvergne may be mentioned, which has been used for the churches and other buildings of Clermont, some of which were old at the time of the first

¹ Besides the specimens of serpentine contained in the Economic Collection, others may be seen in the collection of Minerals, case 25.

² See also Mineral case No. 25.

crusade ; and the felspathic greenstone of Penmaenmawr (I67) in North Wales, which, on account of its hardness and toughness, is eminently suitable for paving-stones, and which is quarried on an immense scale for such purpose and shipped to all parts of the British Islands.

Limestone (I67, I68).

True limestone is composed of carbonate of lime ; when the lime is replaced in part by magnesia, the rock passes into dolomitic limestone and dolomite. But, from the builder's point of view, these rocks are all included under the one term. Unaltered limestone is generally a fine-grained rock, breaking with a conchoidal fracture, or sometimes oolitic : altered or metamorphic limestone is more or less highly crystalline. The color of the rock is very varied, but the prevailing tint in unaltered limestone is some shade of gray, while crystalline limestone is often pure white. *Marble* (I67) includes all limestones which will take a good polish. Common limestone, as well as oolite, is largely used as a building stone in districts where it is abundant ; while the uses of marble in architecture are too well known to need description. Statuary marble (I67) is a kind having a saccharine texture (like loaf-sugar) and a pure white color. There is a good series of polished specimens of marble in the collection from various localities in England and Italy (I67, I68) which show well the varied appearance of the rock due to differences in color and texture. The statue of Her Majesty the Empress at the head of the grand staircase is of marble from the celebrated quarries of Carrara near Genoa, which supply statuary marble to a large part of the civilized world.

Sandstone (I68).

Sandstone is a rock composed of grains, siliceous as a rule, and mostly quartzose, bound together by some cementing material, which is generally silica, carbonate of lime, or oxide of iron. The durability of the rock varies greatly, some kinds crumbling easily when exposed to the weather, whilst others are extremely durable. Fine-grained sandstone admits of elaborate carving for architectural purposes. In England and elsewhere sandstones are obtained from numerous and widely separated geological groups.

Slate (168).

Slate is an extremely fine-grained argillaceous rock, in which a fissile structure, called cleavage, has been developed by intense pressure at right angles to the direction in which the rock splits. Some inferior slates (so called in commerce, although in a strict geological sense not slate at all) owe their fissile structure to extremely thin bedding, not to cleavage. The use of slate for roofing is almost universal in the British Islands.

Perhaps the most celebrated quarries in the world are those of North Wales. Specimens of slate of 1st, 2nd, and 3rd quality from the immense excavations at Penrhyn (Caernarvonshire) are in the collections (168). The rude blocks obtained by blasting are first split into slabs of moderate thickness with stout chisels (168). These are sub-divided to the required degree of thinness with 'splitters'—thin triangular chisels with a broad keen edge (168). The resulting slates of irregular shape are then cut into rectangles with a long knife or 'dresser' (168), used with a chopping motion. At the back of the dresser there is sometimes a spike for making nail-holes in the slates.

Rarer ornamental stones (168).

Under this head come fluorspar, alabaster, rock crystal, agate, jasper, jade, malachite, &c. These are only partially represented in the economic collection, but fine examples of them may be seen amongst the collection of minerals.¹

BUILDING AND ORNAMENTAL STONES.*INDIAN.***Granite, Gneiss, &c. (169).**

If a line be drawn from Rhotasgarh, on the Sone, to Goa, the immense stretch of country to the south-east is mainly occupied by crystalline rocks, which are used more or less as building stones. Many of the Hindu temples in Southern India may be cited as examples. Similar rocks are also found in the Narbada valley,

¹ Fluorspar, in cases 6, 7; quartz in its different varieties, 11, 12; jade, 15; lapis lazuli, 19; labrador felspar, 20; gypsum, 30; malachite, 34. See Popular Guide to the Minerals.

Bandelkhand, and some other parts of peninsular India, as well as in the Himalayas.

Serpentine (169).

Serpentine occurs in Burma (169) and is said to be exported thence to China; it is also found in the hilly country to the east of Assam (169). In the southern part of the Mirzapur district a handsome *verd-antique* marble (169), composed of alternating irregular layers of serpentine and dolomite, is known to occur, but it has never been worked owing to its remote and inaccessible position. Serpentine has been found in the Kadapa and Bellary districts (169) in Madras, and in several parts of the Himalayas; in the collection is a 'poison cup' of this material from Shiggar in Báltistan (169), which, if the current idea is to be accepted, will break if a poisoned beverage be poured into it.

Steatite (169, 170).

The best known Indian steatite is probably that so much used at Agra for the manufacture of delicately carved ornamental articles (170). It is obtained from a mine near Mora (170), a village north-west of Hindaun in the State of Jaipur (Rájputána). The bed is about 2 feet thick, and cubes of pure stone of from 1 foot to 18 inches can be obtained. The cost at the mine, including royalty and various fees, is 10¼ annas per maund.

Steatite is quarried somewhat extensively at Sikana (170), 20 miles east-south-east of Tehri in Bandelkhand, and turned into plates, bowls (170), &c. It is also found, and has been worked, in several other parts of India. "Vessels of this and similar materials are used for culinary purposes, especially by high-caste Hindus, throughout India, although they cost much more than earthenware vessels. The properties they possess, which commend them especially for this purpose, are that they do not communicate any unpleasant taste to food, as do unglazed earthenware vessels, and that they will stand great heat, so that they can not only be used for cooking, but can be purified by fire, a matter of no slight importance to the class mentioned." ¹

¹ V. Ball, Economic Geology, p. 440..

Potstone, a rock allied to steatite, but of more uncertain composition, is worked in several parts of India for similar purposes, as for instance in the Manbhum (169) and Singhbhum (169) districts of Chutia Nágpur. Finished plates of ordinary size fetch about $2\frac{1}{2}$ or 3 annas at the mines, and larger ones, about 15 inches diameter, 4 annas; they are exported in some quantity to Calcutta, where they are sold at perhaps three times the above rates.

Volcanic rocks (170).

To the north-west of a line drawn between Rhotasgarh and Goa there is an area of nearly 200,000 square miles occupied by immense overflows of volcanic rock. "Many of the trap beds furnish admirable building stone, extremely tough, yet not excessively hard, quite free from joints and not liable to injury by exposure. At the same time some caution is necessary in selecting basaltic rocks for building purposes. None of the beds containing zeolites, interspersed in irregular strings and veins throughout the mass, are good. They are soft, brittle, and liable to decompose. None of the ash beds are equal in strength, toughness, or resistance to the atmosphere, to the solid basalts, and no rock of a red color should ever be taken for building purposes. It is almost always decomposed. Amongst the very best beds are the porphyritic basalts such as those which form so large a proportion of the rocks on the Thull Ghât."¹ The above rule, that zeolitic trap should be avoided, is not without exception, an amygdaloid quarried at Parkurni (170), near Hoshangabad, having been much used on the Great Indian Peninsular Railway with excellent results. The paving stones used for the Calcutta tramways (170) are made of Bombay trap.

Volcanic rocks are also largely developed in the Rájmahál Hills. The harder kind of basalt (near 170) has been employed to a considerable extent for building stone, and is also quarried for the supply of Calcutta with road metal (170).

Limestone (171, 172).

A beautiful white crystalline marble is quarried at Tsagyen (171), near Amarapura, and amongst other

¹ W. T. Blanford, Mem. G. S. I., VI, 217.

purposes is used by the Burmese for carving images of Buddha.

The Táj Mehál at Agra, "a dream in marble designed by Titans and finished by jewellers," is built of white crystalline limestone from the marble quarries of Makrana (I71) in Jodhpur¹ (Rájputána). They are extensively worked at the present day. "From distant parts of India orders for temples are sent to Makrana, and the blocks of pure marble cut and ready to be put in place are forwarded to their destination."² Besides its architectural uses the marble is fashioned into tables, vases, and other ornamental articles (I71).

Amongst other localities where crystalline marble is found in India may be mentioned the 'marble rocks' near Jabalpur. A white saccharine dolomite (I71) can be obtained there in blocks of considerable size, but it has not been worked of any extent as yet. The quarries at Hánsapathar, near Barákar on the East Indian Railway, are also worth notice on account of their comparative proximity to Calcutta. A white marble (I71), not of the best quality, but obtainable in large blocks, can be had there in unlimited quantity. As yet it has only been used for lime-burning and as a flux.

Amongst sedimentary limestones available as marbles may be mentioned the fossiliferous cretaceous limestone found on the Námbár River and elsewhere (I71) in Assam, and a somewhat similar rock occurring in the Trichinopoly district (I72) of Madras. A jurassic limestone (I71), owing its yellow and reddish color to oxide of iron, is found near Jaisalmir in Rájputána, and has been worked to some extent.

The limestones in India available as ordinary building stone are numerous, but it will be sufficient here to notice the sub-recent miliolite limestone (I72) of Kathiawár and Kachh. It is a porous, soft, and easily worked stone of oolitic structure, and mainly composed of foraminifera. Large quantities of it are shipped to Bombay, and elsewhere, from Porbandar in Kathiawár, and hence it is known as 'Porbandar stone.'

'*Kankar*'³ of the more massive kind (near I71) is

¹ V. Ball, Economic Geology, p. 464. According to Dr. W. W. Hunter the marble came from Jaipur.

² *Ibid.*

³ For a description of this rock, see p. 13.

sometimes used for building, as in some of the bridges of the Ganges Canal in the North-Western Provinces.

Kankar is an excellent material for road metal, and is used throughout India wherever available. The small nodule, or broken stone, when wetted, stamped down, and allowed to dry, form an extremely smooth and fairly durable surface.

Sandstone (I73).

Sandstone of excellent quality is obtainable from rocks of various ages. At Sasunia Hill, 17 miles south-south-west from Rániganj, an ancient quartzite (I73) has been largely quarried for paving purposes, for which it is well suited on account of its hardness and toughness. It is known in the trade as 'Burdwan paving stone.'

Perhaps the finest, certainly the most largely worked, building stones in Northern India are those derived from the sandstones of the Upper Vindhyan series (near I75). Allahabad, Benares, Agra, and Dehli have all drawn their supplies from thence, and of such material have been erected the grandest monuments of the Mughal dynasty. Akbar for his palace at Fattipur Sikri and the forts at Agra and Allahabad, Shah Jehán for portions of the Táj at Agra as well as for the Jamma Masjid at Dehli, and Aurangzeb for that at Benares, all availed themselves of those resources. In modern times some of the largest engineering works in India, including the piers of the railway bridges over the Jumna at Allahabad and Dehli, have been constructed of such stone. Enormous blocks of ashlar can be obtained, while, on the other hand, the fine grain of the stone enables it to be carved with the most elaborate tracery. Near Allahabad and at Mirzápur (near I75) and Chunar, there are quarries which supply the neighbouring cities, and from the last-mentioned place the well-known 'Chunar stone' is sent as far even as Calcutta. St. John's Church is built of it. The same rock has also been largely worked at Dehri (near I75) in connection with the Sone Canal works. The quarries near Agra are in a Vindhyan sandstone of different and younger age.

The Gondwána series (I73 & near I75) also supplies good stone, although generally more coarse-grained than that from the Vindhhyans. Tálchir sandstone has been

used in the Godáveri irrigation works at Dumagudiam (173), and near Barákar it is made into dishes (173) similar to those of steatite mentioned above. A considerable portion of the High Court in Calcutta is built of Barákar sandstone (quarried at Barákar). Within the Museum a sample may be seen in two of the pillars of the entrance hall, and flagstones of the same material are used for the pavements. Jurassic sandstones (173) are largely worked in Kachh. Amongst the most noted quarries are those at Dhrangadra (173), the stone from which has been used for the new palace of the Rao of Kachh and other edifices at Bhuj. One of the minor uses to which the same stone is put is in the manufacture of water-bottles (173), constructed in two pieces neatly cemented together, which keep the water at a low temperature owing to their porosity.

Laterite (near 175).

“Laterite, in its normal form, is a porous argillaceous rock, much impregnated with iron peroxide, which is irregularly distributed throughout the mass,” and which “exists either entirely in the state of hydrated peroxide, or else partly as hydrated and partly as anhydrous peroxide.”¹ Laterite is a widely distributed rock in India, covering in the aggregate a very large area. It is used in many places as a building stone. It possesses the property, in common with some other building stones, but in a higher degree, of hardening by exposure after it has been raised from the quarry. Amongst many parts of India where it is largely developed, Midnapur (near 175) and Kattak (near 175) may be mentioned. It has been used extensively in those districts for anicuts, locks, &c., in canal work, and has been found well suited for such purposes.

Laterite is much used in India for road metal, making smooth and fairly durable roads.

Slate (175, 176, & near do.).

Slate has been found, and worked to some extent, in several parts of India. Although the material is only fairly good in some, it has been found of excellent quality in others. In many cases the fissile character

¹ W. T. Blanford, *Manual of Geology*, p. 349.

of Indian slate is due to lamination (very thin bedding), not to cleavage.¹

In the Kharakpur Hills (I75), near Monghir, there is a band of slate, from 6 to 12 feet thick, which has been quarried and mined by the natives of the district for centuries. The material is of only fairly good quality: ordinarily the slates at the quarries are from $\frac{1}{4}$ to $\frac{1}{2}$ an inch thick (I75.) Plates, &c. (I75), are also made of the stone to some extent.

Slate has also been found, but not worked to any extent, in the Khásia and Jaintia Hills (I75), Manbhum and Singhbhum (I75) in Chutia Nágpur, and at Chiteli in Kumaon (I75). The best slate hitherto discovered in India is probably that occurring in the Punjab Himalayas near Dharmsala (I76) and Dalhousie (I76), especially the latter. "It has proved of first rate quality for roofing purposes; its fissility is all that need be desired; it dresses easily, and can be procured of ample size."²

Very good slate also occurs at Rewári in the Gurgáon district (I76 & near do.). It has been largely used of late on the Rewári-Ferozpur Railway for roofing and other purposes. A slab (between I79 & I82), measuring 9 feet $\times$ 5 feet $\times$ 1 inch, serves to show the capabilities of the Rewári quarries.

Rarer ornamental stones (I74).

Alabaster—i.e., white saccharine massive gypsum—occurs with other varieties of gypsum at Kiura (I74) and elsewhere in the Salt Range.

Rock crystal has been found at Bijkomar in the Sambalpur district (I74). At Aurangpur, near Delhi, there are pits from which the same mineral was formerly extracted. Whether these were the source where the material was obtained from which the Dehli rock crystal ornaments (I74) were made, is not known.

A very handsome green *avanturine quartz* (I74) occurs near Bellary in Madras.

Several varieties of quartz, *chalcedony*, *agate*, *carnelian*, *onyx*, *sardonyx*, *jasper*, *bloodstone*, are found in the Deccan traps, where they occur in geodes or filling cracks in the rock. Some of them are obtainable in

¹ See p. 4.

² H. B. Medlicott, Mem. G. S. I., III, 176.

immense quantities, and they are cut and polished on a considerable scale in Western India, the colors of the finished stones being in many cases artificially produced by heat and other means. The most important centres of the industry are Cambay and Broach in Guzerát; the stones are also worked up at Jabalpur and some other places. Generally speaking, they are not obtained direct from the trappean rocks, but from gravels formed of trappean debris. Rock crystal and amethyst are also found, but not in pieces from which stones of any considerable size can be cut. Specimens of some of the above are included in the economic collection (I74); others will be found in the collection of minerals (II, I2).

Jade is found in the Mogoung district of Upper Burmah (I74), where there used to be, and apparently still is, a large trade in the mineral, as many as one thousand men being sometimes engaged in digging for it. At Momein in China, whither a large proportion of the mineral is sent, a pair of bracelets of the finest jade cost about Rs. 100.

In the year 1882-83 over 4,000 cwt. of jade, valued at Rs. 9,00,000, were exported from Burma to Straits Settlements, the great bulk of which was doubtless for shipment to China.

Jade of an inferior kind occurs in the southern part of the Mirzapur district (I74) in the North-Western Provinces.

Although beyond the limits of India, the jade mines of the Karakash valley (I74, also I5) in Turkistán may be mentioned here, as they and other mines in the same Kuenlun range have yielded large quantities of jade to the Chinese, who seem to have been acquainted with it during the last two thousand years.

MATERIALS FOR LIME AND CEMENTS.

INDIAN.

Lime, &c. (I78, I79).

Limestones of the most varying geological ages, embracing the crystalline marble of the oldest rocks at one end of the scale, and recent coral at the other, are burnt in India for lime.

Amongst the crystalline limestones, that at Hánsa-pathar (I78), near Barákar on the East Indian Railway,

may be mentioned, as affording an unlimited supply of stone within a moderate distance of Calcutta. An analysis of an average sample yielded about 83 per cent. of carbonate of lime, the remainder being chiefly quartzose sand. The rock was used as a flux by the Bengal Iron Company when their furnaces were in blast, and has also been burnt to some extent. A purer stone, but occurring in limited quantity only, has been found on the Putro River (I78) north of the Karharbári coal-field. Boulders of crystalline limestone washed down from the mountains to the eastward (I78) are burnt for lime in Upper Assam. In many other parts of India a similar rock is used.

The calcareous rocks of the submetamorphic, or transition series, are frequently dolomitic, as for instance at the marble rocks, and elsewhere, in the Jabalpur district :¹ to a limited extent they are used for lime.

Both in Bandelkhand and in the Sone valley, the Lower Vindhyan strata include a large proportion of limestone, but there are not many places where the conditions of carriage allow of its being advantageously worked for more than local use. The most favorable positions are Rhotasgarh (I79), whence the stone, or burnt lime, used to be taken down the Sone to the Ganges ; it can now be transported to the railway by the Sone canal ; and Katni (I79), in the Jabalpur district, where the stone is largely quarried, and the lime exported as far even as Calcutta. The best Katni stone contains about 95 per cent. of carbonate of lime.

The Bhánrer limestone, of Upper Vindhyan age, covers a large area in Rewah and Bandelkhand. The East Indian Railway runs along the outcrop in the Tons valley west of Maihar (Myhere), and crosses it near Satna (I79). The stone is burnt in the latter position, which has an advantage over Katni in being nearer Allahabad and the markets beyond, but it is doubtful whether the lime is equally good.

The Gondwána series contains but little limestone. At Panchet Hill (I78) near Barákar a rock belonging to the lower strata has been quarried both for lime and as a flux, but it is not equal in quality to the Hánsa-pathar stone mentioned above.

¹ Dolomites are grouped under the head 'Magnesia,' case 95.

Limestone, probably of cretaceous age, is largely developed in Rámri Island (I78), as well as on the mainland of Arakán. It often has the appearance of indurated chalk, as for instance at Yanthek creek (I78) in Rámri, the limestone of which gave on analysis about 95 per cent. of lime carbonate. The Arakán stone appears to be well worth notice for the supply of the Calcutta market with lime.

The Lameta and intertrappean limestones are burnt in some localities, as for instance in the Jabulpur district (I79).

The nummulitic limestone "on the southern face of the Khási and Jaintia Hills (I78) afford an inexhaustible source of lime, which has been drawn upon for many years under the name of Sylhet lime, to supply the wants of Calcutta and the greater part of Lower Bengal, wherever lime made from kankar is not available. According to the statistical account of Assam there are 26 quarries in the Khasi and 7 in the Jaintia Hills. . . . During the year 1876-77, the estimated export was 1,600,000 maunds, valued at Rs. 4,80,000."¹ Nummulitic limestone has also been worked at Rohri (I79) in Sind.

The sub-recent miliolite limestone of Kathiawár (I79) and Kachh has been already alluded to as a building stone.² The 'spoil' and chippings at the quarries are turned to account for lime-burning.

The most widely diffused and most commonly utilised source of lime in India is '*kankar*.' This is a "concretionary carbonate of lime, usually occurring in nodules, in the alluvial deposits of the country, and especially in the older of these formations. The commonest form consists of small nodules of irregular shape, from half an inch to three or four inches in diameter, and composed within of tolerably compact carbonate of lime, and externally of a mixture of carbonate of lime and clay. The more massive forms are a variety of calcareous tufa, which sometimes forms thick beds in the alluvium, and frequently fills cracks in the alluvial deposits, or in older rocks."³ At the Indian Portland Cement Company's

¹ V. Ball, Economic Geology, p 469.

² p. 7.

³ W. T. Blanford, Geology of India, p. 381.

works at Rániganj, kankar, mixed with enough calcite to raise the proportion of carbonate of lime to the proper amount, is used for the manufacture of Portland cement. Specimens of kankar from several localities (178, 179) are included in the collection.

Calcareous tufa, a rock which often has a cellular spongy texture, and which is deposited from lime-charged water, especially about waterfalls and places where spray and drip favor evaporation, is also a common source of lime in some parts of the country, as in the Dárjiling district (178), Kámrup (178) in Assam, &c.

In some places along the coasts of India, recent *coral* is available for lime. By an elevation, amounting to more than 20 feet at some points, which has taken place within the last couple of centuries in the Arakán islands south of Akyab (178), large quantities of coral have been raised above tidal limits. There it is not of much value as limestone is abundant also; but in some parts of India, the Laccadive (179) and Maldive islands for instance, it is the only source of lime available.

Gypsum (180).

The most abundant supply of gypsum in India is doubtless in the Salt Range (180), where the mineral occurs in enormous quantities associated with rock salt and marl in beds of not newer than Silurian age. A consignment of this gypsum recently tried at the Calcutta School of Arts yielded a plaster of Paris of excellent quality.

Gypsum occurs in several parts of the Himalayas (180), but some of them are so difficult of access that the mineral is practically useless.

An inferior sort of gypsum which is used for the coarser purposes in the School of Arts at Jaipur, where it costs Rs. 3 to Rs. 3½ per maund (including Re. 1 import duty), is obtained at Nagor (180) in Jodhpur.

Gypsum, chiefly in the form of selenite, occurs somewhat abundantly in Sind (180), Kachh (180), and Kathiawár (180), in rocks which are mostly of tertiary age. The material has not been utilised to any extent.

The Utatur (cretaceous) beds of the Trichinopoly district (180) in Madras contain a considerable amount of gypsum, which is available for common purposes, but which is too much mixed with clay for the finer uses.

MATERIALS FOR GRINDING AND POLISHING.*INDIAN.***Millstones, &c. (181).**

There is but little demand in India for ordinary millstones except for some of the European factories, the stones used in which are generally imported. A large trade, however, is done in many of the Indian provinces in 'quernstones' or small handmills for grinding corn. Amongst the materials used for the purpose may be mentioned an arkose occurring in the sub-metamorphic rocks of the Kharakpur Hills (181), and a somewhat similar rock quarried at Lakhiserai (181); a somewhat felspathic, cellular Bhánrer (Upper Vindhyan) sandstone used at Fattipur Sikri (181), near Agra; and a ferruginous, cellular, lower tertiary sandstone worked at Ránikot (181) in Sind. At Rájula, in Southern Kathiawár, a trachytic rock (181) is used for the same purpose.

Corundum (181).

A magnificent bed of granular massive corundum occurs in gneiss at Pipra (181 & near 182), a village in Rewah near the border of the Mirzapur district. It has been traced for about half a mile, with a maximum thickness of perhaps 30 yards or more. There is a practically unlimited supply of the mineral, which is quarried to a certain extent, and apparently finds its way in small quantities over a large part of India. It can be bought in the Calcutta bazár amongst other places. The cost at Pipra is very low, including merely the wages of the quarrymen and a small royalty, but more than 100 miles of carriage to the railway at Mirzapur, over a road part of which is impassable for carts, raises the price very much. If better communications could be established, the mineral would, from its abundance, and superiority over ordinary emery, be well worth attention for export on a large scale.

Granular massive corundum also occurs in the Khási Hills (181), and is used locally by the villagers for grindstones. It is not known whether the mineral occurs in large quantity or not.

Corundum occurs in several parts of the Madras Presidency; the Bellary district (181) amongst others,

where it is found in dull irregular crystals, either scattered about loose on the surface, or in a decomposed gneissose matrix, from which it is obtained by digging shallow pits. About the year 1880, several thousand rupees worth are said to have been exported to England.

Powdered corundum (181) is used by the Indian lapidaries for cutting gems and other stones, either with a revolving iron disk, or with a wire attached to a spring-bow. The same material mixed with lac is made into disks, &c. (181), which are used for grinding gems and other substances.

Garnet (181).

Garnet is sometimes used as a substitute for, more commonly as an adulterant of, emery. Massive garnet occurs in very large quantity in parts of Hazáribágh (181) and adjoining districts of Chutia Nágpur. A somewhat similar material is also found in Coimbatore (181). In parts of the country, crystallized and detrital garnet (181) is so abundant that it could be collected in some quantity.

MATERIALS FOR GRINDING AND POLISHING.

FOREIGN.

Millstones (182).

Amongst the very best materials for millstones is a kind of cellular chert obtained from a tertiary fresh-water formation of the Paris basin, and known as 'French buhrstone' (182). It is largely exported to England, America, and other parts of the world, including even India.

A cellular gray lava is extensively quarried for millstones at Niedermendig (182) near Andernach on the Rhine, and exported in various directions.

In Hungary a trachytic rock, known as 'millstone porphyry' (182) is used for the same purpose.

Grindstones (182).

The material ordinarily used for grindstones is some variety of sandstone, which should possess keenness of 'bite,' uniformity of texture, and a sufficient amount of cohesion. The Newcastle grindstones (182), said to be

known all over the world, are obtained from the coal-measures, as are also those from Bilston (182), in Staffordshire. The 'blue grit' (182), from the same county, and the Yorkshire grindstones (182) also have a good reputation.

Scythestones (182).

Sandstone is also the material used for scythestones (182).

Hones (182).

"Hones, or oilstones, as they are generally termed by the workmen using them, are obtained from the varieties of the metamorphic schists and slates which are sufficiently compact, and in which the particles of quartz are extremely minute and regularly disseminated, so as to give them a uniform consistence. Among the varieties most prized are the Turkey oilstones (182), obtained from the interior of Asia Minor, of a yellowish or bluish color, of very close grain, often flawed and cracked, and therefore rather brittle, and requiring to be backed with slate or set in wood; the German razor-hone (182), or novaculite, from the slate-hills in the neighbourhood of Ratisbon, of keener bite and tougher texture; the Arkansas oilstone (182), from North America, consisting of a very fine, white, amorphous silica, of excellent bite, but rather brittle and expensive; the Welsh slate or oilstone (182), a tough fine-grained siliceous slate, but of rather unequal texture; the Charnley Forest oilstone (182), a strong and serviceable whetstone, from Leicestershire; and the water-of-Ayr or snake stone (182), apparently an altered shale of grayish mottled color, rather soft in texture, and chiefly used for polishing copper-plates and the mouldings of ornamental marbles. As the name implies, most of these whetters are used with oil, and are chiefly employed in giving the last or finished edge to the finer-cutting tools and implements."¹

Grinding and polishing materials, generally used in a powdered state (182).

Emery is, like corundum, a natural form of alumina, but differs from it in containing a considerable propor-

¹ D. Page; Economic Geology, p. 205.

tion of iron oxide; hence it is generally inferior to corundum in abrasive power. It is obtained chiefly from near Smyrna in Asia Minor (I82), and some of the Grecian islands. The crushed stone is passed through a succession of sieves and separated into portions of varying degrees of coarseness (I82), '8-hole emery' (I82), for instance, being that which passes through a sieve of 8 holes to the linear inch, and is retained by the next finer sieve. The finest powder usually prepared is termed 'flour emery' (I82).

Pumice (I82) is a kind of spongy or frothy lava, so light as sometimes to float on water. It is used both in fragments (I82) and in powder (I82).

Tripoli (I82) is a soft friable substance composed of the siliceous shields of microscopic animalculæ. The fine powder is much used for polishing purposes.

Rotten-stone (I82) is a siliceo-aluminous compound resulting from the decomposition of impure limestone, the lime being removed by the percolation of water charged with carbonic acid.

Crocus (I82) and rouge (I82), both of which are oxide of iron, and potte or putty powder (I82), which is oxide of tin, are artificially prepared polishing powders, the natural minerals of the same composition not being suited to the purpose.

MATERIALS USED FOR CERAMIC WARE.

FOREIGN.

In this section are samples of the raw materials used in the manufacture of porcelain (I83) at the Royal Works, Worcester. These include China clay, Cornish stone, fireclay, red clay, felspar, flint and bone.

China clay, or *kaolin*, is a product of the decomposition of felspar, and is the purest form of clay obtainable. It must be free from iron and other foreign substances which would tend to destroy the whiteness of the porcelain made from it. That used in England is obtained near St. Austell (I83) and other parts of Cornwall, by washing it out of a decomposed granite (I83). The rock, which, aided by a little manual labor, easily falls to pieces in water, is carried by a current through a long channel to a series of 'catch-pits' or setting tanks. The larger fragments and sand (I83) are deposited in the

channel, from which they are removed from time to time, while the coarser inferior clay (183) mixed with particles of mica, &c., settle in the first tanks, and the finest kaolin in the last (183).

'*Cornish stone*' (183), also called '*China stone*,' is a granite similar to that from which kaolin is prepared, but in a less decomposed state.

Fireclay is a clay which, owing to its freedom from alkalies, lime, &c., is possessed of a high degree of infusibility. As it generally contains a little iron, fire-bricks (under 186) or other articles made from it are more or less colored.¹ English fireclay is obtained from the coal-measures, where it occurs in layers beneath the seams of coal. Stourbridge (183) in Worcestershire is a well-known locality, Aberdare in Glamorganshire (183), Garnkirk (under 186) and Glenboig (under 186) in Lanarkshire, and Westphalia (183) in Prussia, are other places amongst the numerous ones where it is obtained.

Felspar (183) is one of the constituents of granite, some varieties of which are extremely coarse and contain the felspar in large masses. The material used in the English potteries is generally obtained from Sweden.

Flint (183) is obtained from the chalk of South-Eastern England, through which it occurs in irregular nodules. Both felspar and flint are calcined (183) at the potteries, by which they lose their color, and are rendered brittle and more easily pulverised.

Bones (183) are also calcined (183), the resulting material, which is essentially phosphate of lime, being known as 'bone ash.' '*Fritt*' (183) is an artificial preparation used for the glaze on the finer kinds of pottery.

In the same section are samples of the materials used in Messrs. Minton's pottery works at Stoke-upon-Trent.

Gannister (under 186), a nearly pure siliceous sandstone occurring below the coal-measures of the North of England, may perhaps be included in this section. It is finely ground (under 186) and used for lining Bessemer converters (in the acid process), making very refractory fire-bricks (under 186), tuyeres (under 186), &c.

¹ Fireclay is used in porcelain factories for making the 'saggars' or vessels in which the porcelain is baked.

MATERIALS USED FOR CERAMIC WARE.*INDIAN.*

India has never been celebrated for the finer kinds of ceramic ware, only the coarsest pottery, such as can be produced from any good brick-clay, being in common use throughout the country. As a natural consequence our knowledge of the finer clays of India is still far from complete.

Kaolin, derived (as in Cornwall) from the decomposition of a stanniferous granite, is found near Mergui (184) and in several other parts of Tenasserim. It is probably of widely extended occurrence in the Malay Peninsula in connection with the tin-bearing granite.

Kaolin is obtained at Kussumpur (185) near Delhi from a decomposed granite. The rock is elutriated and the washed kaolin made up into small cakes (185) which are chiefly used for white-washing. The blue and white Delhi pottery (185) is probably made from the same material.

Kaolin also occurs in the South Canara district (185) and in several other parts of India.

A decomposed gneiss resembling Cornish stone has been found at Dárjiling (184), which was experimented on at the Madras School of Art. Excellent stoneware (184) was made from it when mixed with kaolin.

A whitish clay is found in several places near Rániganj (184) beneath a capping of laterite; in some cases, at least, it is due to the decomposition of coal-measure shale. It is largely employed in the potteries there, the best kind being used for the finer pottery, and the rest for coarser articles, such as drainage pipes.

Coal-measure shale from the coal mines (184) is ground at the same works for *fireclay*, which is sent into the market both as such and made, with pounded quartz, into fire-bricks (184). The latter, amongst other applications, were used in the blast furnaces of the Bengal Iron-works at Barákar.

Good fire-bricks have been made in the Jabalpur jail (185) from a white clay obtained near the station from the Upper Gondwána beds. A similar material has been found in the same strata near Chandia (185) in Rewah, which gave satisfactory results when tested on a small

scale. As both these clays are nearly white after firing they would probably be found suitable for pottery of the better kind.

A clay not unlike that of Jabalpur, but apparently from rocks of a different age, found near Chandgarh (185) in the Narbada valley, was used in admixture with pounded quartz (185) for making fire-bricks (185) at the Barwai Iron-works.

MATERIALS FOR GLASS-MAKING.

FOREIGN.

Glass is an amorphous silicate, or mixture of silicates, the bases in which are generally soda, potash, lime, and oxide of lead. These, mixed with sand in the proper proportions, are fused together at a high temperature. The composition of the principal kinds of glass may be represented as follows:—

Sheet (187), plate, and crown (187) glass—silicate of soda and lime.

Bohemian glass—silicate of potash and lime.

Flint glass (187)—silicate of potash and lead.

Bottle glass (187)—silicate of soda, lime alumina, and iron.

A series of specimens from Messrs. J, Hartley & Co.'s glass-works at Sunderland illustrate the materials used. Of these, sand (187) forms the principal ingredient in all glass. It should be as nearly as possible pure silica. Sand containing much iron is unfit for any but common bottle glass (187), to which it gives a dark-green color. Sand, however, is rarely perfectly free from iron, and the color produced thereby in transparent glass is destroyed by adding a little oxide of manganese (187), arsenious acid (187), or nitrate of soda (187). Of the basic materials, the most important are sulphate (187) and carbonate (187) of soda (the former has the advantage of being much cheaper than the carbonate), carbonate of potash (187), carbonate of lime in the form of chalk (187), caustic lime (187), and red lead (187).

Colored glass is produced by the addition of various metallic oxides in small quantity to the materials before fusion. Oxide of chromium (187) or bichromate of potash (187) gives the glass an emerald green tint;

oxide of cobalt (I87), a beautiful blue ; oxide of copper (I87), ruby red, green, or blue, according to the way in which it is used ; oxide of iron (I87), green and yellow ; oxide of uranium (I87), greenish-yellow ; and oxide of manganese (I87), purple.

A series of specimens (in miniature) from Messrs. Chances' works at Birmingham illustrate the manufacture of sheet and crown glass. The molten glass is tested from time to time by taking out samples (I87) from 'the glass pot' on the end of a rod ; when homogeneous and free from bubbles (I87) it is fit for use. In making *sheet glass*, the end of an iron tube is dipped into the molten material, and when a sufficiently large globular lump (I87) in a pasty condition has been attached, the workman blows into the tube and expands the glass into a 'boule' (I87) or bulb. Standing on a plank over a pit, he holds the blowpipe downwards, and by swinging it backwards and forwards, at the same time keeping it in revolution and blowing into it, he expands the boule into a cylinder (I87) 5 or 6 feet in length. The end of the partially cooled cylinder is then reheated, while the workman closes the blowpipe with his thumb, the expanding air bursting open the end (I87) which is shaped with a suitable tool until it is the same diameter as the cylinder. The latter is then detached from the blowpipe, allowed to cool, the cap (I87) cut off with a diamond, and the cylinder slit longitudinally in the same way (I87). It is then reheated and opened out with an iron rod into a flat plate, which is annealed by slow cooling.

In the manufacture of *crown glass* the commencement of the process is similar to the above, but the boule (I87), instead of being elongated into a cylinder, is flattened into a discoid form (I87) by rapid revolution. One side of this is opened out (I87), the glass reheated until very soft, and expanded by further rapid revolution into a disk (I87) some 5 feet in diameter, which is annealed by slow cooling.

MISCELLANEOUS ECONOMIC PRODUCTS.

INDIAN.

Mica (I88).

Mica, often, but erroneously, called 'talc,' is used for lanterns, doors for stoves, for transparent photographs

and several other purposes. The thinness and elasticity of its foliæ, its toughness and capability of withstanding fracture, and non-liability to crack from sudden changes of temperature, render it superior to glass for such uses. The quality of the mineral depends on its being in a perfectly unaltered condition, its transparency and freedom from cloudiness caused by internal foreign matter, the absence of minor cleavages which render it liable to split into ribbons and triangles, and the planeness of its fissile surfaces. Mica mines are worked in Hazáribágh (188, also 18) , Gya (188), and neighbouring parts of the country, the rock in which the mineral occurs being an extremely coarse granite.¹ The method of mining is extremely primitive, the trenches and holes being abandoned at a trifling depth, owing to the risk of collapse and difficulty in keeping them dry. If the industry were taken up in a systematic way, the outturn could be largely increased. A considerable proportion of the best mica now raised finds its way to Calcutta, whence it is exported to Europe. The value has increased greatly of late years, plates of large size (which are much more valuable than small ones in proportion to their dimensions) fetching very high prices. The wholesale prices in Calcutta for rough mica of good quality are about as follows at the present time (August 1883):—

Mica yielding trimmed pieces of 6 to 12					Rs. 20		per md. of 82 lbs.	
sq. inches in area								
„	„	„	„	„ 12 „ 30	„	35 to 40	„	„
„	„	„	„	„ 30 „ 50	„	60 to 70	„	„
„	„	„	„	„ 60 „ 70	„	80 to 100	„	„

In India, mica is used at Benares, and other places, for painting on, and the scrap mica is made into spangles for the ornamentation of temples, banners, clothes, &c.

Asbestos (188).

Asbestos² has been found in Garhwal (188), and appears to be plentiful in some parts of Afghanistan. It is said to be used for making brooms in the Gabar Mangal country (188), and at Segai Kángah Khosh, two days' journey from Thal, it is reported to be so plentiful

¹ An inexhaustible supply of felspar could also be obtained from the granite if there were a demand for it.

² See foreign asbestos, p. 24.

that the people make it into ropes. Kuram (188) on the Kohat frontier is another locality from which it has been obtained.

Lithographic limestone (188).

Limestones from various parts of India have been tried for lithographic purposes, and some of them have been actually employed on a limited scale; but none of them have ever come into extensive use. Stones imported from Europe hold complete command of the market.¹

Some forty years ago specimens of Bhánrer limestone from near Rewah (188) were submitted to a practical lithographer for trial, and reported on very favorably by him. He found that the impressions from the larger piece came off well, and considered the quality of the stone decidedly good, as it resembled the German lithographic stone more nearly than any Indian limestone he had previously met with. The stone was subsequently tried in the Government lithographic press at Allahabad, but with rather unfavorable results.

A Lower Vindhyan limestone from Nimach (188) has been tried, and gave fairly good impressions. Limestone of the same age from Talikot (188) in the Kaladgi district of Bombay has been experimented on, but no demand for the stone has arisen. The yellow Jurassic limestone of Jaisalmir (188) already alluded to under the head of Marble, has been reported on very favorably, being, it is stated, perfectly adapted for the more ordinary, although not for finer, lithographic purposes.

Clay for washing, &c. (188).

Certain kinds of clay are used in several parts of India as a detergent (188); others again are eaten (188).

MISCELLANEOUS ECONOMIC PRODUCTS.

FOREIGN.

Asbestos (189).

Asbestos is a fibrous form of tremolite or actinolite, which admits of being woven into cloth. It is unalterable at a red heat—hence its name from ἄσβεστος,

¹ See foreign lithographic limestone, p. 25.

incombustible,—and cloth made from it is said to have been used by the ancients for wrapping the bodies of persons of distinction in during cremation. Owing to the ease with which asbestos cloth could be cleaned by fire, the material was also called amianthus, from ἀμίαντος, undefiled.

Of late years asbestos has sprung into great demand for a variety of purposes. The raw material (189), after the fibres have been opened out and cleaned (819), is spun into yarn (189) which, both as such and twisted into rope (189), is largely used as packing for steam-engines. Asbestos millboard (189) is employed for packing the joints of steam-pipes, pipes for conveying acid, &c. The yarn is woven into cloth (189) which forms an admirable material for filtering in chemical works on account of its being unacted on by even the strongest acids. It has also been used of late for making fire-proof curtains in theatres, and other purposes of a similar kind. Ground asbestos (189) is used both for filtering and as a fireproof paint. Mixed with some clay or other material and made into irregular lumps (189), asbestos has been employed as a radiator of heat in gas stoves.

Lithographic limestone (189).

The best lithographic limestone is obtained from the quarries of Solenhofen (189) near Munich, where the art of lithography had its birth, and from whence the stone (of oolitic age) is exported to all parts of the world. Good serviceable stones have usually a yellow or bluish-gray color, are compact and uniform in texture, and free from veins, flaws, or spots; a steel point makes an impression with difficulty, and the stone breaks with a conchoidal fracture.

CARBON.

GRAPHITE.

INDIAN.

Graphite, also known as plumbago and blacklead, is a form of crystalline carbon, generally found in metamorphic or plutonic rocks. Its use for 'blacklead pencils' is well known, but only a small part of the amount annually raised is consumed in that way. Large

quantities are employed in the manufacture of crucibles (190), 'blacklead' for polishing stoves, &c., and in a powdered state graphite is used as a lubricant, for coating non-conducting materials in electro-metallurgy (190), and for facing moulds in foundries (190), &c.

The best graphite hitherto obtained in India appears to be that found in the neighbourhood of Trivandrum (190) in Travancore, especially that recently obtained at Velurnád (190). The mineral occurs in gneiss and in a form of laterite due to superficial alteration of gneiss. It has been, and is, worked commercially, but not apparently on any large scale. Graphite also occurs in the Tinneveli (190) and Vizagapatám (190) districts. It is used in the latter for giving a polish to pottery, and is sold in Vizianagram at 24 lbs. for a rupee. The graphite of Southern India is not sufficiently fine for pencils, but is available for crucibles.

Graphite has also been found in Sambalpur (190), in several parts of the Himalayas (190), and in some other parts (190) of Northern India, but generally of very inferior quality, or trifling quantity.

Although not strictly Indian, the graphite of Ceylon (190) may be included here. Diggings for the mineral are scattered over every part of the island, and fresh discoveries are frequently made. The average amount exported during the seven years ending 1877 was 6,500 tons per annum. Ceylon graphite is remarkable for its purity, some samples containing more than 99½% of carbon. It is largely imported into England, where it is used for making crucibles (those manufactured by the Plumbago Crucible Co. of Battersea (190) are composed of about equal parts of graphite and Stourbridge fireclay), and in powder for electrotyping (190) and facing moulds in foundries (190), &c.

COAL.

INDIAN.

The coal of India belongs to several district geological periods which include—

Lower Tertiary.

Cretaceous.

Upper Gondwána (Jurassic).

Lower Gondwána (Permo-triassic).

Neglecting the Upper Gondwána coal, which is of little importance, the coal of Peninsular India¹ is almost exclusively Lower Gondwána, while the coal of extra-peninsular India is almost exclusively cretaceous and tertiary.

Looked at with respect to the relative importance of the different coals, the Lower Gondwána takes undisputed pre-eminence. In it alone have mines on any considerable scale been sunk as yet, and (excluding foreign coal) it alone supplies the Indian railways and mills with mineral fuel. Next in importance comes some of the tertiary coal, which occurs in beds of immense thickness in Upper Assam, but which owing to its remote position has not been systematically worked as yet, although steps are now being taken in that direction. Some of the cretaceous coal-fields contain large quantities of fuel, but, like the tertiary, they have not yet been opened out. The Upper Gondwána coal is not of much importance, but has been worked to some extent in one or two places.

Lower Gondwána Coal.

The Lower Gondwána coal may be described as a laminated bituminous variety in which dull and bright layers alternate, the amount of incombustible matter in the former being far greater than in the latter. Much of the coal does not cake freely, while a not inconsiderable proportion will not do so at all. From particular seams, however, in the Rániganj, but more especially in the Karharbári, field, fairly good coke is made. The percentage of ash in the coals brought to market averages 10 to 15 per cent., while the average proportion of fixed carbon is under 55 per cent. in coal from the Rániganj field, and probably about 10 per cent. higher in that from Karharbári. The moisture varies a good deal in coals from the different fields. In those of the Godávári and Wardha areas it is exceptionally high, being often 14 per cent., while in the Rániganj field the average is not more than 4·8 per cent. The quantity of sulphur and phosphorus is very variable in different seams; 31 Rániganj coals gave an average of sulphur ·85 per cent. and phosphoric acid ·83.²

¹ *i. e.* India south of the Indo-Gangetic plain.

² Economic Geology, p. 62.

Compared with average English coal, the Lower Gondwána contains a higher percentage of ash and lower percentage of combustible matter, and hence is inferior in heating power. Thus while the average theoretical calorific power of the former is given at about 7,700 to 8,200 heat units, that of 31 Rániganj coals was only about 6,500.

The total outturn of Lower Gondwána coal in 1881 was one million tons.

Rániganj field (191, 192).

A line of coal-fields extends from Rániganj westwards along the valley of the Damuda River. Of these the longest known, the largest, and by far the most important, is the Rániganj field. It has been worked since the early part of the present century, and in the year 1881 the outturn was 560,000 tons. The East Indian Railway passes through the middle of the field and conveys the coal up-country for the supply of the railway system there, and to Calcutta for consumption in the mills, by sea-going and river steamers, and in making gas, &c. The cost of steam coal at the pit's mouth is Rs. $2\frac{1}{2}$ to Rs. 3 per ton, and in Calcutta about Rs. 8 or Rs. 9. The following analyses indicate the composition of the coal.

	Average composition of 31 coals.	Sánktoria seam.
Fixed carbon	53.20	63.3
Volatile matter (exclusive of moisture)	25.83	} 27.5
Moisture	4.80	
Ash	16.17	9.2
	100.00	100.0

The Sánktoria (192) may be taken as an example of the best coal in the field. It is supplied to sea-going steamers, and has been used for making coke (192).

The coal-measures include (in descending order) the

Rániganj group.
Ironstone shale group.
Barákar group.

The second of these contains iron ore in abundance but no coal. There are comparatively few mines in the

Barákar rocks, but some of the coal obtained from them is amongst the very best in the field, the Dumakunda (191) and Benodakatta (191) having each shown a theoretical heating power of about 7,000 heat units. The seam at Kásta (191) is remarkable for its thickness, which is about 34 feet. As a rule, however, the Barákar seams are inferior to the Rániganj, some of them having been much injured by the intrusion of basaltic dykes, as at Taldánga (191). On this account, as well as from the greater accessibility of the upper measures, the great majority of the mines are in the latter. (Numerous samples of the coal may be seen in and under case 192.)

Some of the coal from both groups exhibits a peculiar spheroidal structure (192, Sitarampur), round balls of various sizes up to more than a foot in diameter breaking away from the mass when the coal is mined.

Karhárbri field (193).

The Karharbári field, although of small size, containing only 8 square miles of coal-bearing rocks, is second in importance only to the Rániganj, from the western limit of which it is distant about 30 miles to the north-west. The branch line connecting it with the East Indian Railway gives it a slight advantage over Rániganj in the carriage of coal to the North-Western Provinces and Punjab. In 1881, 370,000 tons were raised, of which the larger proportion was burned on the railways up-country.

There are three principal seams in the field, all of which supply good coal (193), the best being that from the lowest, or main, seam (193), which is 12 to 16 feet thick. The average quality of the coal is superior to that of Rániganj, while the best coal is very little, if at all, inferior to good English steam coal.

	Average composition of 6 Karharbári coals from 3 seams.	Coal from main seam.
Fixed carbon	63·66	66·84
Volatile matter	24·01	24·00
Ash	12·33	9·15
	100·00	100·00
Sulphur	·66	·42

The coal-bearing strata of Karharbári are considered to be on a somewhat lower geological horizon than the Barákar beds in Rániganj.

Coal-fields in the Upper Damuda Valley (193).

From Rániganj a line of coal-fields stretches westward along the valley of the Damuda, including the Jharia, Bokáro, Rámgarh (193), and North and South Káranpura (193). They contain an immense reserve of fuel, but have not yet been worked, owing to their remoteness from the line of railway.

Rájmahál Hills (193).

Coal also exists in the Rájmahál Hills (193), and a considerable quantity was raised during the construction of the East Indian Railway, but as the fuel is mostly of inferior quality, the working of the mines has been almost discontinued. In 1881, about 200 tons was extracted.

Sikkim (194).

The only known occurrence of the Lower Gondwána coal-measures in extra-peninsular India is in the Eastern Himalayas. From the frontier of Nepál a narrow band has been traced, in the lower hills, for 30 miles or more to the eastward. Outcrops of coal are numerous, but the rocks are so contorted and the seams so squeezed that mining would be extremely difficult; and as the coal is crushed to powder (194) or so friable (194) that it falls to pieces in handling, it could only be useful after artificial consolidation. Good patent fuel (194) and coke (194) have been experimentally made from it with the addition of agglomerating materials, but the difficulty of mining and expense of subsequent treatment are fatal to the coal being practically used. It differs from the Lower Gondwána coal of peninsular India in having lost a considerable part of its volatile matter, thus approaching anthracite in composition.

					Average composition of 5 coals.	Rakti Naddi.
Fixed carbon	.	.	.	.	70·66	79·3
Volatile matter	.	.	.	.	9·20	7·6
Ash	.	.	.	.	20·14	13·1
					100·00	100·0

Coal-fields in the Sone basin (194).

In the basin of the Sone are the Daltonganj (194), Singrauli or Kotah (194), Bistrampur (194), Lakhanpur (194), Sohágpur (194), Umeria (194), and other coal-fields, some of which have been worked on a trifling scale. But their remoteness from the existing railways has as yet been prohibitive to systematic mining.

The proposed railway through Umeria and Sohágpur will make those fields the nearest source of supply for North-Western India.

Mopáni coal-field (194).

The Mopáni coal-field, in the Narbada valley, is about 80 miles west-south-west from Jabalpur, and is connected with the Great Indian Peninsular Railway by a short branch line. Situated as it is nearly half way between the coal-fields of Bengal and Bombay with its sea-borne coal, the Mopáni field is in a most advantageous position for the supply of a long stretch of railway. Unfortunately, however, the expectations originally formed have not as yet been fully realised, and only small quantities of fuel (194) have been raised, amounting to 20,000 tons in 1875, but only 18,500 in 1882. The deep pits now being sunk will, it is hoped, lead to more satisfactory results.

Coal-fields in the Godáveri basin (81).

The Warora coal-field is connected by a branch line with the Nágpur section of the Great Indian Peninsular Railway, to which it has supplied considerable quantities of fuel; the outturn in 1881 being 60,000 tons, costing Rs. 2-10 at the pit's mouth. The following assays give a fair idea of the composition of the coal:—

	No. 1.	No. 2.
Fixed carbon	45'4	43'70
Volatile matter (exclusive of moisture) .	26'5	33'75
Moisture	13'9	9'55
Ash	14'2	13'00
	100'0	100'00
Sulphur	2'85	'25

The low percentage of fixed carbon and high percentage of moisture show the coal (81) to be inferior to the average of that from the principal Bengal fields.

Better coal than the Warora has been found at Pisingaon (81), 13 miles to the west-south-west. An experimental pit was opened there, but eventually abandoned, as it was considered that the balance of advantages lay with Warora, to which consequently the railway was constructed.

Coal has been found, but not worked, in several other places lower down the Godáveri valley.

Coal-fields in the Máhanadi basin (81).

In the basin of the Máhanadi are the Udepur (81), Korba (81), and Hingir (81) coal-fields, and just beyond it the Tálchir (81). None of them have as yet been worked, but mines will doubtless be opened in the event of direct railway communication being established between Calcutta and Nágpur.

Upper Gondwána Coal.

Sone and Narbada Valleys (82).

The Upper Gondwána beds of the Sone and Narbada valleys contain occasional seams of coal, as on the Máhanadi River (82), and at Lameta Ghát (82) on the Narbada; the seams, however, are generally thin and irregular, and the coal of inferior quality, so that it is of little value. It was worked at Lameta Ghát for a time during the construction of the Great Indian Peninsular Railway, and used for local purposes.

Salt Range (82).

At Kálabágh, in the Salt Range, masses of carbonised wood (82), occurring in beds of jurassic age, excited some attention at one time. Careful examination, however, has shown that the supply of fuel obtainable is quite insignificant.

Cretaceous Coal.

Assam (82).

The most important cretaceous coal-fields in India are in the Gáro, Khási, and Jaintia Hills, where there are a number of detached fields. Most of these are mere patches, but one at least is of considerable size; this, the Daranggiri field, has been estimated to contain

76 million tons of coal in the main, which is the only workable, seam (82), (Garigithem outcrop). The following assays indicate its composition :—

	No. 1.	No. 2.
Fixed carbon	47·7	51·8
Volatile matter (exclusive of moisture)	33·1	39·4
Moisture	11·5	6·2
Ash	7·7	2·6
	100·0	100·0

The only field which has been utilised as yet is the small one at Maubilarkar (82), which has supplied the station of Shillong with coal for many years.

The cretaceous coal (82) has a peculiar character, which is persistent throughout the cretaceous area of Assam. The texture is compact and splintery, with smooth conchoidal fracture, and the coal gives a dull woody sound when struck; it has the additional peculiarity of containing numerous specks and small nests of fossil resin. Some of it is highly pyritous, but coal almost free from such impurity also occurs, like that of the main Daranggiri seam.

Burma (82).

Coal, which from its similarity to the cretaceous coal of Assam, is believed to be of the same age, occurs in certain parts of Burma, the Lenya River (82) in Tenassarim, and Thingadaw (82) above Mandalay, amongst others.

Tertiary Coal.

Upper Assam (83).

Next to the Lower Gondwána coal-fields of peninsular India, the most important fuel deposits in the Empire are undoubtedly those of Upper Assam, on account not only of the abundance of the coal, but also of its excellent quality. There are several distinct coal-fields to the east and south of Dibrugarh, along the skirts of the Nága Hills; of these the most important, taking the quantity of coal, facilities for mining, and position into account, are the Makum (83) and Názira (83). Preparations are now being made for systematic mining in the

Makum field, and a railway is under construction to convey the coal to the Brahmaputra; within the next year or two, therefore, the coal will probably be largely used in the Assam steamers and on the railways of Eastern Bengal.

Some of the seams are of great thickness, 20, 40, and even 70, feet of coal having been measured in one bed. The greater portion of the coal is hard and firm, withstanding the weather for long periods. It differs in outward appearance from the Lower Gondwána coal in its homogeneous structure and the absence of lamination,¹ and from the cretaceous coal in not breaking with a smooth conchoidal fracture, and the absence of fossil resin.² Its composition is indicated by the following assays :—

	Average composition of 23 coals.	Seam near Tikák.
Fixed carbon	56·5	66·1
Volatile matter (exclusive of moisture)	34·6	33·5
Moisture	5·0	... ³
Ash	3·9	·4
	100·0	100·0

The Tikák coal is an example of the best fuel in the field. It will be seen on comparing the above assays with those previously given, that the Upper Assam coal contains far less ash than the Lower Gondwána, and a larger proportion of volatile matter. The mean theoretical calorific power of 10 Makum coals was found to be about 7,400 as against 6,500 for the Rániganj coals.⁴ The only drawback the Upper Assam coal possesses is the objectionably large proportion of sulphur which some of it contains; the best, however, does not include more than 1 or 1½ per cent. Most of the coal cakes strongly.

Khási and Jaintia Hills (83).

Tertiary coal exists in the Khási and Jaintia Hills in considerable quantity, and has been worked at one or two spots, as at Cherrapunji.

¹ P. 27.

² P. 33.

³ Assayed after expulsion of moisture.

⁴ P. 28.

Arakán (83).

It has also been found in Rámri (83) and Cheduba (83) Islands off the coast of Arakán, but not in workable amount.

Pegu (83).

Some promising coal of the same kind has recently been discovered near Henzáda (83) in Burma.

Himalayas (83).

Lignite, occurring in irregular nests, or as distinctly recognizable trunks or branches of trees, is scattered through the Siwálik sandstones which fringe the Himalayas, almost without interruption, from the Brahmaputra to the Indus (83, Raidak River, Western Duárs and S. of Khátmandu). On account of the insignificant quantity obtainable in any one locality, this lignite is useless as a source of fuel. It has, however, given rise to numerous imaginary discoveries of useful coal, so that it may be well not to leave it unnoticed here.

Salt Range (83).

Tertiary coal has long been known to exist in the Salt Range (83), and numerous attempts have been made to work it, but without any promise of success.

Sulimán Range (83).

Similar deposits have also been discovered at various places in the Sulimán Range (83), but no really valuable seams of coal are known to occur anywhere in the Panjáb or Sind.

Travancore (83).

At Warkilli (83) in Travancore, lignite occurs in tertiary strata, and has sometimes been spoken of as a possible source of fuel, but it seems highly improbable that any workable deposit will be found.

COAL.¹*FOREIGN.*

Coals admit of classification in various ways; they may, however, mostly be included under anthracite and bituminous coal.

¹ In the year 1882-83, 630,000 tons of foreign coal was imported into India, of which 590,000 tons came from Great Britain. The quantity landed at Bombay far exceeded that at any other port.

Anthracite (84).

Anthracite (84, Caermarthenshire) contains from 90 to 95 per cent. of carbon and only a small proportion of volatile matter. It has a high specific gravity (1·3 to 1·7), and breaks with a conchoidal lustrous fracture. It does not soil the fingers when handled. When burnt it gives but little flame and no smoke, but produces an intense heat.

Anthracite is derived from the alteration of bituminous coals through the loss of their volatile ingredients. There is a gradual passage from one class of coal into the other: bituminous coal, with a low percentage of volatile matter, and approaching anthracite in composition, is frequently called '*steam coal*,' from its being especially suitable for marine use. The best steam coal in England comes from South Wales (84).

Bituminous coal (84).

Bituminous coals (84, Newcastle, S. Staffordshire) contain a large proportion of volatile matter, which is driven off as gas during combustion; hence such coals burn with considerable or much flame, and with more or less smoke. They are divided into caking and non-caking, or free-burning, coals. The former, when heated in close ovens or retorts, undergo a partial fusion at first, then the gaseous matter is driven off, and the fixed carbon and ash remain behind in the form of coke (84). Coke is prepared in large quantities for iron-smelting, fuel for locomotive engines, and other purposes. It is also obtained as a by-product in gas-making.

In all coal-mining a large amount of 'smalls' (coal in small fragments) is produced, which, in the case of caking coals, can be utilised by conversion into coke. The smalls of non-caking coal cannot be thus treated, but are available for 'patent fuel' (84), in which the powdered coal is artificially mixed with some agglomerating material. According to one process the coal is mixed with coal-tar and pitch, and after strong compression in moulds, is raised to a red heat in ovens, by which the pitch, &c., is decomposed. Patent fuel, from the rectangular shape of the bricks, admits of very economical storage for marine use.

'*Cannel*' coal (84, Wigan) is a variety of bituminous coal. It is non-laminated, breaks with a flat conchoidal

fracture, and does not soil the fingers, ignites very readily, burning with a bright steady flame. It contains a very large proportion of volatile matter, and is largely employed for gas-making.

Lignite (84).

Lignite is a term used rather vaguely, but is generally applied with reference chiefly to the age of the coal. Coals of cretaceous or tertiary (84) age have been thus designated. By some, however, the term is applied to all coals more recent than the true carboniferous.

Peat (84).

Peat (84) is a more or less spongy substance formed in the swamps of cold and temperate regions through the annual growth and decay of numerous marsh-plants. In some cases the deposit attains a thickness of 30 to 40 feet or more. In Ireland (84), and some other parts of Europe where coal is scarce, peat is used on a considerable scale in its raw state as a fuel for household purposes. Owing, however, to its spongy texture and want of density, and the amount of moisture it retains, peat has, bulk for bulk, a much lower heating power than coal. To obviate this disadvantage, 'compressed peat' (84) is produced by thoroughly drying the raw material, reducing it to powder, and subjecting it to intense pressure. By heating the compressed peat in close vessels, a 'peat charcoal' (84) is produced, which is stated to be far superior to wood charcoal, and equal to coke made from coal.

Coal-tar products (85).

In the destructive distillation of coal for the production of gas, there collects in the condensers a quantity of ammoniacal water known as 'gas liquor,' which floats on a heavier stratum of 'coal-tar' or 'gas-tar' (85). Both these by-products are utilised, the former as a source of ammonia, while from the latter, thanks to the rapid progress made during late years in organic chemistry, a wonderful series of compounds is now produced. The 'coal-tar colors' (85) include a long array of red, yellow, green, blue, violet, brown, and black dyeing or coloring materials, many of them of magnificent brilliancy. Carbolic acid (85), largely used as a

disinfectant and antiseptic, is one of the most important products; cresylic acid (85) is applied to similar purposes. From carbolic acid a number of other compounds are derived, amongst which is sulpho-carbolic acid, various salts (85) of which are used in pharmacy.

PETROLEUM-ASPHALT.

INDIAN.

The most important oil-bearing regions in India are Burma and Assam. Oil is also found in the Punjab, but, up to the present time at least, no large quantities have been obtained. In all three provinces the petroleum occurs in connection with the older tertiary rocks.

Upper Burma (86).

The oil-fields which have been most extensively worked as yet, indeed the only ones which have been continuously worked on a large scale, are those of Upper Burma (86). Rather conflicting estimates have been made as to the yield; the latest is for 1873, the quantity obtained in which year is put down at a little over 10,000 tons. At an earlier period the yield would appear to have been considerably greater, but it has been adversely affected of late years by the enormous quantities of oil produced in America, some of which is imported into Burma itself. In 1879-80, about 4,000 tons (only a portion of the total yield), valued at about Rs. 155 per ton, was exported from Upper to British Burma. The oil is dark colored, and becomes thick and viscid at moderately low temperatures, such as are experienced in the cold weather. Hence it is sometimes called 'Rangoon tar' in commerce. Its viscosity is due to its containing some 10 per cent. of paraffin.

The crude oil (86) is refined by the Rangoon Oil Company. The products obtained include paraffin (86) which is made into candles (86), lubricating oil (86), oil for 'batching' jute (86), and burning oil (86). The outturn of such oils in 1881 is put down at 1,400,000 gallons, valued at Rs. 5,00,000.

Pegu (86).

Petroleum has also been obtained in Pegu (86), but not in any large quantity.

Arakán (86).

Oil has long been known to occur in the Arakán islands, and within the last few years experimental borings have been made in Rámri Island (86) and the Barongas (86). The results obtained in Rámri have been very satisfactory. Two companies are now engaged in working the oil, the quantity obtained by the older company in 1881 being stated at 5,400 barrels, valued at Rs. 40,500; most of this was obtained at Myinbyin (86). 1,000 barrels of refined oil, valued at Rs. 10,000, were turned out of the company's refinery in the same year.

The Arakán oil differs from that of Upper Burma in having a lighter color, being sometimes the color of sherry or brandy, a lower average specific gravity, and in remaining perfectly mobile at 62° F. One sample gave by fractional distillation—

Petroleum spirit	.	.	.	.	.	23'35
Oil suitable for burning	.	.	.	.	.	46'35
„ for lubricating purposes	.	.	.	.	.	27'80
Loss	.	.	.	.	.	2'50
						100'00

Assam (86).

The petroleum of Upper Assam (86) appears to be closely connected in its origin with the existence of coal, the known oil-springs being all situated in, or close to, the coal-fields.¹ It is dark colored like the oil of Upper Burma, but remains fluid, or becomes only slightly viscid, at 62° F.

More than one attempt has been made to work the petroleum of Makum (86). These sufficed to show that the oil was obtainable in large quantity, but were not successful financially, owing to the remote position of the field, and consequent difficulty and expense of carriage. This difficulty, however, will soon be a thing of the past, through the opening of the new railway from Dibrugarh to the Makum field.

Where the petroleum oozes to the surface and saturates the surface soil, as at Bapu bor pung (86), it forms a sort of earthy bitumen.

¹ See p. 33.

Punjab (86).

Petroleum has been found in the Salt-range (86), Rawal Pindi (86), Kohat (86), and Bannu (86), and has been worked in one or two places. Only small quantities, however, have been obtained.

PETROLEUM-ASPHALT.*FOREIGN.***Mineral Pitch (87).**

Petroleum passes by insensible gradations into viscid bitumen, and the latter as insensibly into asphalt, or solid bitumen, often called 'mineral pitch.' One of the most remarkable localities in which the latter is found, is the 'Pitch Lake' of Trinidad (87), which is about a mile and a half in circumference: the bitumen is cold and solid near the shores, but gradually increases in temperature and softness towards the centre, where it is boiling. The ascent to the lake from the sea, a distance of three quarters of a mile, is covered with the hardened pitch, which is largely exported. Amongst other less noted localities in which the same material is found, Darfeld (87) in Westphalia may be mentioned, where it occurs in fissures in chalk marl.

Asphalt (87).

The substance commonly called asphalt in commerce is a limestone impregnated with bitumen. Such is the well-known asphalt of Pyrimont (87) in the Jura mountains, and the Sicilian asphalt (87). The raw material is prepared by crushing and sifting, after which the powder is added by degrees and well mixed with pure bitumen, which has been previously melted in a large iron boiler. For asphalt of average composition the proportions employed are about 2 tons of powdered asphalt to 3 cwt. of bitumen. The mixture, called mastic (87), is finally ladled out into moulds and allowed to solidify into blocks, in which state it is sold. The most important use of asphalt mastic is for paving, for which purpose it is mixed with sand or gravel: it is also used for roofing, as a lining for walls, and other purposes, for which it is well suited on account of its impermeability to damp. In India it is applied to floors as a protection against white-ants.

In the year 1882-83, about 40,000 cwt. of asphalt was imported into India.

BORON.

INDIAN.

Borax (89).

In several parts of Hundes (89) in Western Tibet and in the Trans-Himálayan part of Kashmir (89) extensive deposits of borax are found. Some of these occur as crusts around the shores, or deposits on the bottom, of extremely saline lakes which have no outlet; others like that of Puga (89) in Ladák are connected with the issue of hot springs. The Puga springs vary in temperature from 135° to 178° F., and are situated in the middle of the borax grounds. Owing to the elevation of the ground, which is about 15,000 feet above the sea, the deposits can only be worked for a few months in the year.

The deposit consists of a mixture of borax, sulphate and carbonate of soda, common salt and other impurities. After a fall of rain, and subsequent evaporation, an efflorescence appears at the surface consisting mainly of the non-boracic (which are the more soluble) salts; when this is removed a layer 2 or 3 inches thick of partially purified borax is exposed, which is collected by the traders. The unaltered deposit beneath, which is thus laid bare, undergoes a similar natural purification near the surface when the next rain falls.

Three qualities of the material collected are recognised according to the amount of impurity present; the third quality is rejected, while the first and second are mixed together, packed in bags, and transported on sheep and goats across the passes to India. The crude borax (called *tshále* in Tibet and *kacha sohága* or *tinkár*, whence our trade name *tincal*, in Northern India) from Puga (89) is chiefly refined at Sultanpur in Kulu; that from Hundes is refined at Morádabad (89) amongst other places. The purified material is called *pakka sohága*.

Comparatively recent discoveries of boracic compounds in less inaccessible parts of the world than the Trans-Himálayan region have done much to reduce the trade from India, although considerable quantities are still exported. In the year 1882-83, the export amounted to 24,000 cwt., valued at Rs. 5,70,000.

BORON.*FOREIGN.*

Besides native borax, native boracic acid, borate of lime, and borate of magnesia, or boracite, the last of which is found more especially at Stassfurt (89) in Prussia, are utilised for the production of the salt.

Borax is used for glazing pottery and china, as an ingredient in some kinds of glass, as a flux in chemical operations, as an antiseptic, in medicine, and for other purposes.

FLUORINE.*INDIAN.*

Fluorspar is not known to occur in India in any quantity, although small specimens have been obtained from one or two places (89).

FLUORINE.*FOREIGN.*

In England (89) and elsewhere fluorspar occurs in abundance. Besides its use as an ornamental stone already alluded to,¹ and as a flux in some metallurgical operations, it is largely employed for the production of hydrofluoric acid, a compound used for etching on glass, and in chemical analysis.

PHOSPHORUS.*INDIAN.*

India is unfortunately very deficient in natural mineral phosphates, no deposits of any importance having yet been discovered. Coprolites have been found in the Lameta beds of Písdura (89) in East Berar, and in the Upper Gondwána strata of Maleri (89) in the Nizam's dominions. Apatite (89) has only been found in isolated specimens.

In the valley of Khátmánda there is an extensive deposit of stiff blue-gray clay, containing specks of blue iron earth (phosphate of iron) freely scattered through

¹ P. 4.

it (89), which is largely employed throughout the valley as a manure. The proportion of phosphate is, however, too small to allow of the clay being put to any but local use.

PHOSPHORUS.

FOREIGN.

Mineral phosphates (89).

Amongst the numerous mineral phosphates which are treated by the makers of artificial manures, may be mentioned the South Carolina land phosphate (89) which occurs in rough nodules in eocene strata, the phosphatic nodules found in the crag of Suffolk (89) which are known as coprolites in the trade, and the phosphate of Curaçoa (89) and other West Indian islands, termed 'rock-guano' in commerce. The above contain the following average percentages of tricalcic phosphate :—

South Carolina land phosphate	.	.	.	53½
Suffolk coprolites	.	.	.	57
Curaçoa rock-guano	.	.	.	70

Tricalcic phosphate being insoluble in water, the raw materials are inapplicable as manure in their natural state: after being powdered, therefore, they are treated with sulphuric acid and converted into a mixture of soluble phosphate of lime and gypsum, which is known in trade as 'superphosphate' (89).

The phosphate from Redonda (89) and Alta Vela (89) Islands, in the West Indies, consist mainly of phosphate of alumina. They are used as a source of alumina in the manufacture of alum, while the phosphoric acid is employed for making artificial manure.

SULPHUR.

INDIAN.

Native Sulphur (90).

Deposits of native sulphur are known in several places on the borders of India, some of which are worked. The remote position, however, of most of them, and the consequent difficulty of carriage, has prevented any very extensive output.

Sulphur has been found on Barren Island (90), a dormant volcano in the Bay of Bengal, but it does not seem probable that the mineral could be worked profitably.

There are sulphur mines in the Trisul Ganga Valley (90) in Nepál, but nothing is known as to the outturn.

In the Puga valley (90) in Ladák, there is a rich deposit of sulphur close to the hot springs already noticed in connection with borax.¹ The mines belong to the Maharajah of Kashmir, and the annual outturn about 20 years ago was estimated at about 500 or 600 maunds. Later information is not available. The method of purification is extremely wasteful, all but the richest ore being thrown away. The best parts are melted in pots, the stony impurities skimmed off the surface, and the sulphur cast into copper moulds about 7 inches in diameter and 2 inches deep.

Near the hot spring of Pir Zinda (90) in the Sori pass through the Luni Pathán hills (a portion of the Sulimán range), sulphur occurs disseminated through gypsum, and is said to be abundant. The process of manufacture is very simple; a common earthen garra filled with the ore is placed over a fire, and the sublimed sulphur (90) condensed in a second garra inverted over the first.

Sulphur occurs in a similar way at the Sanghar pass (90) in the Sulimán range. It is purified by sublimation, and the sublimed sulphur (90) subsequently formed into cakes (90) by melting and pouring into moulds.

Sulphur is also made near Sibi (90) in Kandahár.

Iron Pyrites (90).

A mineral so ubiquitous as iron pyrites (90) is naturally found in many parts of India, but no really important source of the ore is known as yet.

SULPHUR.

FOREIGN.

Sulphur (90).

The two most important ores of sulphur are the native mineral (90), from which refined sulphur is prepared by melting or by sublimation according as the

¹ P. 41.

raw material is rich or poor in sulphur, and iron pyrites, (90) a mineral containing 46·7 per cent. of iron and 53·3 of sulphur, a portion of which can be extracted by sublimation. Sulphur is sent into the market in large blocks, as roll sulphur (90), and as flowers of sulphur (90), the first two of which are made by pouring the melted substance into moulds, and the last by sublimation. Amongst the many uses of sulphur, the most important are in the manufacture of sulphuric acid and gunpowder, and for sulphuring hops and vines as a preservative against some diseases.

Sulphuric acid (90).

Sulphuric acid (90) is made by burning either sulphur (90) or iron pyrites (90) and conducting the fumes into large lead-lined chambers, where they are further oxidised by nitrous vapours introduced for the purpose, and absorbed by a layer of water on the floor of the chamber: the 'chamber acid' thus produced is afterwards concentrated by evaporation.

The burnt pyrites when cupriferous (90) is treated for the extraction of copper, and is finally utilised for the production of iron, so that all its constituents are turned to account. In 1882-83, 22,000 cwt. of sulphur and 9,400 of sulphuric acid were imported into India.

SODIUM.

INDIAN.

Salt (91).

India is supplied with salt mainly from four sources, namely, salt imported from abroad, rock-salt obtained from mines in the Punjab, salt procured from salt lakes in Rájputána, and that produced by the evaporation of sea-water. Salt is also obtained by evaporating the water from salt wells, by lixiviating saline earth, and as a by-product in the manufacture of saltpetre.

Enormous deposits of rock-salt occur in the Salt Range of the Punjab. At the Mayo mines (91 and near 93) there are five great beds, having an aggregate thickness of 275 feet, alternating with another 275 feet of *kallar* or impure salt, the whole being intercalated in the upper part of about 1,000 feet of red marl and gypsum. Some individual beds of salt are over 100

feet in thickness. The saline strata underlie beds of doubtful silurian age.

The salt is extensively worked by Government from several mines and quarries, the most important of which is the Mayo. During late years the cost of raising the salt has been about Rs. 2-14 per 100 maunds. The following analyses give the composition of the salt from the Mayo mine:—

	Purest white crystalline salt.	Average good salt.
Chloride of sodium . . .	94·60	93·00
„ magnesium . . .	·71	1·25
„ calcium . . .	...	·50
Sulphate of lime . . .	·77	·75
Earthy matter . . .	trace	trace
Water and loss . . .	3·92	4·50
	<u>100·00</u>	<u>100·00</u>

Large deposits of rock-salt also occur in the Kohát district (91), which are worked extensively by means of open quarries. The salt is very different in age from that of the Salt Range, being probably eocene. Rock-salt, which may be of the same age, is also worked at Mandi.

The following quantities of salt were delivered from the Punjab mines in the year 1882-83:—

	Maunds.	Tons.
Salt Range mines . . .	16,40,000	60,000
Kohát do. . .	4,70,000	17,000
Mandi do. . .	1,00,000	3,700

In Rájputána there are several shallow salt lakes without outlet, from which large quantities of salt are obtained. Of these, the largest is the Sámbar Lake (91), which is about 20 miles long by some 5 miles broad. Its greatest depth, at the end of the rains, does not exceed 3 feet, and in the hottest weather there is but little water left, the surface of the lake bed being then covered with an incrustation of salt. As soon after the rains as the brine attains a sufficient degree of concentration, portions of the lake are cut off by low walls of mud and grass, &c., in order to expedite the evaporation,

and the resulting crust of salt, which is over 2 inches thick, is then removed. Salt is also made by evaporation of the brine in salt-pans. The cost of making salt at the Sámbar Lake varies in different years. In 1878-79 it was Rs. 1-15 per 100 maunds, and in 1881-82 (when it was exceptionally high) Rs. 8-13.

The Didwána Lake is about 4 miles long and $1\frac{1}{2}$ broad; during the rains there is a foot or so of water, but soon after the dry weather commences the lake becomes quite dry. The mode of procuring the salt (91) is different from that pursued at the Sámbar Lake; wells about 15 feet deep are sunk in the lake-bed, and the brine, which rises to near the mouth of wells, is evaporated in shallow pans, about 20 yards square, made of impervious clay.

Salt is also procured from the Phalodi (91), Kachor-Rewasa, and Lonkára Sur Lakes.

The outturn from the two principal lakes in the year 1882-83 was as follows:—

	Maunds.	Tons.
Sámbar Lake	45,80,000	168,000
Didwána „	2,90,000	10,600

Large quantities of salt are manufactured on the coasts of India by the evaporation of sea-water, as in the Puri (91), Katták (91), Ganjam (91), Nellore (91), and South Arcot (91) districts. That made by solar evaporation in shallow pans is known as *panga* salt (91, Puri), while that produced by boiling down the sea-water is called *karkatch* (91, Katták).

Salt is also obtained by raising the water from salt wells and evaporating it in shallow pans. Amongst other localities this method is carried on in the Gurgáon district (91), and until within the last few years was practised in Bhartpur (91).

At Pachbadra (91), in Jodhpur, large quantities of salt are obtained by digging oblong pits in an old river-bed. By continual infiltration and evaporation of brine a crop of salt crystals is formed, which is allowed to grow for about two years, and is then extracted. Crystallisation is aided by sinking branches of a thorny shrub called *moralí* in the pit. In the year 1882-83 5,40,000 maunds, or 20,000 tons, of salt were delivered from Pachbadra.

In some parts of the country salt effloresces on the surface of the ground, and is purified from earth, &c., by dissolving it in water and evaporating the solution. The resulting salt is called *chotia* (91, Gwalior, Karnul).

A further supply is obtained as a by-product in the manufacture of saltpetre¹; such salt is known as *kutla* (91, Bhartpur), and *khári* (91, Bikanír), the latter being an inferior kind used for curing hides.

Salt is throughout India subject to a tax, which, after the land revenue and opium duty, forms the largest item in the Imperial revenue. Except in Burma and the Trans-Indus districts of the Punjab, the tax levied is Rs. 2 per maund. In the year 1881-82 the net revenue derived from salt amounted to £6,900,000 (£1 = Rs. 10).

Carbonate of Soda (91).

Carbonate of soda, mixed with a greater or less proportion of other salts, occurs in parts of India as an efflorescence on the surface of the soil. From the impure material mixed with earth, &c. (91), the salt (91) is prepared by lixiviation and evaporation.

SODIUM.

FOREIGN.

Salt (92).

The foreign salt imported into India is mainly shipped from England. It is also brought from Muscat (92), the Persian Gulf (92), and other places.²

Besides the universal employment of salt as a condiment with food, it is used in immense quantities for various purposes in the arts.

Carbonate of Soda (92).

One of the most important of these is the manufacture of carbonate of soda. According to Leblanc's process, which is that commonly adopted, salt (92) is decomposed by sulphuric acid with the aid of heat, the result being 'salt-cake,' *i.e.*, sulphate of soda (92) and hydrochloric

¹ See p. 49.

² In the year 1882-83, 340,000 tons of salt were imported into India, of which nearly 300,000 tons came from England.

acid, the latter of which is collected as a by-product. The salt-cake is mixed with limestone and coal (92), and heated in a reverberatory furnace until fully decomposed, when the liquid mass is scraped out and allowed to cool. The 'black-ash' (92) thus obtained is a mixture of insoluble sulphide of calcium and soluble carbonate of soda (92), the latter of which is separated by lixiviation with water and evaporation of the solution.

Caustic Soda (92).

Caustic soda (92) is made, according to the most common process, by heating a solution of carbonate of soda with caustic lime (92), the result being insoluble carbonate of lime and a solution of caustic soda, which is evaporated down.

Nitrate of Soda (92).

Nitrate of soda (92), mixed with other salts, is found in beds several feet thick in the dry district of Tarapaca in Northern Chili. It is largely exported under the name of 'Chili saltpetre,' and being cheaper than nitre is extensively used in the manufacture of nitric and sulphuric acids, and as an ingredient in some artificial manures.

POTASSIUM.

INDIAN.

Saltpetre (92).

Saltpetre or nitre is a common natural product in many parts of Bengal, the North-West Provinces, the Punjab (92), Madras (92), &c., and its collection forms an important branch of industry. It occurs, mixed with other salts (especially common salt), as an efflorescence on the surface of the ground, and mixed with the upper part of the soil, in and around villages where decomposing animal refuse is mixed with the earth. The *shora-wallas* (makers of saltpetre, who form a large class) scrape off the efflorescence and a thin layer of the superficial earth (92), and lixivate them in earthen vessels with water: when the solution is pretty well saturated, it is poured into shallow pans of unglazed earthenware, and evaporated by solar heat, aided by the hot winds when available. After sufficient concentration crude saltpetre (92) crystallizes out, which is sent to the refineries and

purified by recrystallization (92). By further evaporation common salt is obtained from the mother-liquors.¹

The *shorawálla* makes fresh collections from the same spots of ground week after week and year after year, the production of nitre being constant as long as the place is inhabited.

Some two-thirds of the total quantity of saltpetre exported from Calcutta comes from Behár. Parts of the North-West Provinces also contribute to the supply, and a little comes from the Punjab. In the year 1882-83 there were about 500 refineries in Behár, which treated 6,00,000 maunds of crude saltpetre and produced 2,90,000 maunds of refined saltpetre, which sold at an average price of Rs. 2-4 per maund.

In the year 1882-83 about 5,50,000 maunds (or about 400,000 cwts. = 20,000 tons) of saltpetre were exported from Calcutta. From Bombay and Madras only a few hundred maunds were sent.

The most important use of saltpetre is as an ingredient in gunpowder.

Sulphate of Potash ; Sylvite (92).

Sulphate of potash (92) and sylvite (chloride of potassium) (92) have been found in association with the rock-salt of the Mayo mines,² but not in such amount as to be of any economic value.

POTASSIUM.

FOREIGN.

Sylvite (92).

Sylvite (92) occurs in large quantity, with other potash-salts, at Stassfurt in Prussia, where they form a thick bed above the rock-salt.

Carbonate of Potash (92).

Carbonate of potash (92) is prepared from sylvite (chloride of potassium) by a process exactly similar to that for making carbonate of soda from salt, already described,³ the production of sulphate of potash (92) and black-ash (92) being intermediate stages in the process.

¹ P. 48.

² P. 45.

³ P. 48.

LITHIUM.*INDIAN.*

Lepidolite, or lithia-mica, occurs in considerable quantity in parts of Northern Hazáribágh (92), as a local constituent of coarse granite, and if there were any demand for lithia in India, the mineral might be utilized as a source of it. An analysis of the mica gave 3.71 per cent.

LITHIUM.*FOREIGN.*

The uses of lithia are very limited, the principal being for medicinal purposes. One of the chief sources of the alkali is lithia-mica (92), which generally contains from 2 to 5 per cent.

STRONTIUM.*INDIAN.*

Celestite, or sulphate of strontia, has been found in connection with tertiary strata at Surdág (93) in the Salt Range, and in Kohistán (93) in Lower Sind. In neither position is it believed to occur in any considerable quantity.

STRONTIUM.*FOREIGN.*

The minerals from which the salts of strontium are prepared include the native sulphate or celestite (93), and the carbonate, or strontianite (93). The most important use of strontia is for pyrotechnic purposes, the nitrate giving a red flame when mixed in proper proportion with the other ingredients in fireworks.

BARIUM.*INDIAN.*

The principal localities in which barytes has hitherto been found in India are the Sabáthu lead mines (93), near Rájpur (93) in the Dehra Dun district, Imlia (93)

near Sleemanabád, in Jabalpur, and the old lead mines at Baswapur (93) in the Karnul district of Madras. It may, perhaps, occur in considerable quantity in the above places, but no definite information is available.

BARIUM.

FOREIGN.

The native sulphate, which is commonly known as barytes or heavy-spar (93), and the carbonate or witherite (93) are the minerals from which the other salts of baryta are prepared.

Sulphate of baryta is employed as a paint, which is known as 'permanent white' (93). The carbonate forms an ingredient of some glass, while the nitrate is used for producing a green flame in pyrotechny.

MAGNESIUM.

INDIAN.

Magnesite (95).

Magnesite, or carbonate of magnesia, exists in large quantity at the 'Chalk hills' (95) near Salem in Madras, where it occurs in the form of veins traversing metamorphic rocks. It has been found in one or two other places (95) also, but apparently not in any considerable amount.

Dolomite (95).

Amongst the many localities in India where dolomite, *i.e.*, carbonate of lime and magnesia, occurs, only a few need be mentioned here.

In the Western Duárs of Jalpáiguri lofty hill ranges bordering the plains are entirely composed of massive dolomite (95), samples of which yielded on analysis—

			Light gray.	White.
Carbonate of lime			59.7	60.5
" magnesia			37.8	38.7
Ferric oxide and alumina			1.0	} .3
Insoluble			.8	
			99.3	99.5

Dolomite occurs profusely in the transition rocks of the Jabalpur district (95). The following analyses show that some of it is a material of great purity:—

	Marble rocks (white.)	Between Dharoli and Deori (gray.)
Carbonate of lime . . .	55.48	52.45
„ magnesia . . .	43.55	38.22
„ iron . . .	.36	2.76
Insoluble . . .	.61	6.57
	100.00	100.00

The dolomite of South Mirzapur (95) and Kulu (95) are amongst those in too remote positions to be of much service at present.

Both magnesite and dolomite can be employed for the production of magnesia and the magnesia salts, of which the most important are the sulphate, chloride, and carbonate. Dolomite is often burnt for the production of magnesian lime, and from this point of view it might be included with the “materials for lime and cements.”¹

ALUMINUM.

INDIAN.

Alum (96).

Potash alum, or sulphate of potash and alumina, occurs native at the Puga sulphur mines (96),² but the quantity is not sufficient to render it worth collection.

In several parts of India alum is made artificially, and in some places considerable quantities are turned out.

In the Amb valley (96), and many other parts of the Salt Range, ‘alum-shale,’ *i.e.*, shale containing a considerable amount of iron pyrites disseminated through it in a rather finely divided state (and often more or less bituminous), is found. When such shale is exposed to the effects of air and moisture, the pyrites is oxidized, and the sulphuric acid unites with the alumina of the shale producing sulphate of alumina, and with the oxidized iron of the pyrites producing ferrous sulphate. The latter partly acts on the shale, producing oxide of iron and a further quantity of sulphate of alumina, and is partly oxidized to ferric sulphate.

¹ . P. 11.

² P. 44.

At Kálabágh, on the Indus, alum is manufactured from such shale. The decomposition is hastened by piling the shale, in alternate layers with brushwood, into heaps 30 or 40 feet high and roasting it at a low temperature, six or eight months being occupied in this process. The roasted shale is subsequently lixiviated with water, the saturated solution drawn off and allowed to settle, and the clear liquor again drawn off. The latter is then boiled in iron evaporating pans, and mixed with the proper amount of *jumsan* (which appears to be impure nitre.) After settling, the concentrated solution is removed to vats, and the alum allowed to crystallize out, while the sulphate of iron remains in the mother-liquor. The crop of alum is then removed, slightly washed with cold water, allowed to dry, melted in an iron pan in its own water of crystallization, and poured into large *garras* or earthen jars, where it is allowed to crystallize. The *garras* are afterwards broken and the mass of alum extracted. In 1848 the quantity of alum produced annually was estimated at about 12,000 maunds, and the works are still in active operation.

Alum shale is very common amongst the coal-measures of Upper Assam (96, Dikhu Valley), but has not been utilized hitherto. When the coal mines now being opened out are in full work, the shale may perhaps attract attention.

At Khetri, in Rájputána, the pyritous and somewhat cupriferosus slate, which is thrown out as refuse from the copper mines there, is utilized for alum-making. The slate, broken into small pieces, is put into *garras* or earthen jars, and lixiviated with water. After the solution has been sufficiently concentrated by pouring it from *garra* to *garra* and leaving it to act on successive portions of fresh slate, it is boiled down in other *garras*: when sufficiently reduced it is left to cool, and thin sticks are introduced on which sulphate of copper crystallizes. The mother liquor is then removed to other *garras*, again boiled down, and nitre added, after which potash alum forms in crystals at the bottom of the vessel. The residual liquor contains sulphate of iron with some alum and sulphate of copper: these mixed sulphates are crystallized by allowing the liquor to evaporate in broken *garras* in the sun. The alum is purified by recrystallization (96), a similar process

being applied to the sulphate of copper. Four (Khetri) maunds of slate are said to yield—

	Sírs.
Sulphate of copper	I
Alum	I
Mixed sulphates	

which are sold at the following prices per (Khetri) maund—

	Rs.
Sulphate of copper	14
Alum	4
Mixed sulphates	I

Alum is manufactured on a somewhat considerable scale at Mharr, in Kachch. The alum-shale (96) is excavated during the rains and exposed for four months in heaps. It is then spread in shallow pans and sprinkled with water; after some time an impure sulphate of alumina, called *phitkári-ka-bíj*, or 'seed of alum', collects in mammillated crusts (96). These are boiled with water in large iron vessels, and an impure sort of nitre, called *súra kar*, added, after which the liquor is placed in earthen vessels and the alum (96) allowed to crystallize. This crude salt is purified by recrystallization (96). About 15 years ago the quantity of alum made annually was stated to be over 8,000 maunds (of 40 seers); later information is not available.

ALUMINUM.

FOREIGN.

Alum (97).

Until recent years most of the alum produced in England has been *ammonia-alum* (sulphate of alumina and ammonia) made according to Spence's process. Coal-measure shale, consisting mainly of silicate of alumina, and containing enough carbonaceous matter to support combustion (97), is slowly calcined (97) in heaps. It is then ground to coarse powder, and treated with sulphuric acid (97), aided by heat. At the same time ammoniacal vapours, obtained by heating gas-liquor (97), are blown in. The solution is run out into cisterns and stirred until cold, in order to obtain

the alum in minute crystals or 'alum meal' (97). This is drained from the mother-liquor, (which is colored green (97) by iron derived from the shale), slightly washed (97) with cold water, and dissolved by a current of steam. The solution is allowed to settle and brought into vats, where the alum separates in large crystallized masses (97), after which the mother-liquor (97) is drained off.

Since the introduction of cheap chloride of potassium from Stassfurt (97), ammonia-alum has been superseded by *potash-alum* (97 and between 97 and 100). The process of manufacture is similar to that just described, except that sulphate of potash made by Leblanc's process¹ is substituted for sulphate of ammonia.

Potash-alum is also made by roasting and lixiviating alunite or alum-stone (97), a basic sulphate of alumina and potash occurring in some volcanic regions, and due to the action of sulphurous vapours on trachyte.

Cryolite (97), a fluoride of aluminum and sodium brought from Greenland, is used for making alum and carbonate of soda.

Sulphate of alumina (97).

Aluminoferrous cake (97) is a sulphate of alumina with some iron, which is made from bauxite (97), a natural hydrate of alumina and iron. Being much cheaper than alum, the cake is, for many purposes, used as a substitute.

CHROMIUM.

FOREIGN.

Chrome pigments (98).

Chromium, named from *χρῶμα* color, in allusion to the fact that all its compounds are colored, serves in the production of numerous pigments. Chrome red (called in the trade Chinese red (98) and Persian red (98) amongst other names) is a basic chromate of lead. Orange chrome (98) is a mixture of chrome red and chrome yellow (98), the latter being normal chromate of lead. There are two kinds of chrome green; one is chromic oxide, the other a mixture

¹ P. 50.

of chrome yellow and Prussian blue (98). Brunswick green is generally an oxychloride of copper, but a mixture (98) similar to that for making chrome green also goes by the same name. Various shades of all the above colors are produced by adding some other material, especially sulphate of lead, which being itself white, gives the color a lighter tint.

CHROMIUM.

INDIAN.

The ore from which all the chromium compounds are prepared is chromic iron or chrome iron ore (98), which generally contains from 40 to 65 per cent. of chromic oxide. From this bichromate of potash is prepared by calcining the finely-ground ore with lime and carbonate of potash, lixiviating the mixture with water and precipitating any lime existing in the solution as chromate, with sulphate of potash. After the addition of sulphuric acid to convert the chromate into bichromate, the latter is allowed to crystallize, while sulphate of potash remains in the mother-liquor. From bichromate of potash the other chromium compounds are prepared.

Chromic iron has lately been found near Port Blair (98), in the Andaman Islands, but it is not yet known whether there is any considerable quantity of it.

Chromic iron occurs with serpentinous rocks in the Hánle Valley (98) in Ladák, probably in large quantity, but it is practically worthless owing to the remoteness of the position beyond the Himálayan snows.

The same mineral is found at the Chalk hills (98), in the Salem district of Madras, in association with serpentine (98) and magnesite.¹ The ore is said to be abundant, and about 50 years ago the manufacture of bichromate of potash (98) was started at the mine; some 10 years later a considerable quantity of ore was shipped to England. The mine was subsequently abandoned, owing, it is said, firstly, to a falling off in the demand for ore, and, secondly, to the difficulty in keeping the workings free from water.

¹ P. 52.

MANGANESE.*FOREIGN.*

Manganese is not used in the arts in the metallic state, although an alloy with iron, known as ferro-manganese, and containing sometimes over 70 per cent. of manganese, is employed in the manufacture of Bessemer steel.

The most important use of manganese ores is in the production of chlorine for making bleaching-powder, &c., and their efficiency depends on the amount of 'available oxygen' they contain, which determines the quantity of chlorine they are capable of producing when heated with hydrochloric acid. When perfectly pure they contain the following quantities:—

	Available oxygen.
Pyrolusite, or peroxide of manganese (98)	. 18.4
Braunite (98)	. 10.0
Manganite (98)	. 9.0
Hausmannite (98)	. 6.8
Varvacite (98)	} Ores of indefinite composition.
Psilomelane (98)	
Wad (98)	

The ores met with in commerce, however, never contain the full theoretical quantity owing to impurities. By far the most valuable ore is pyrolusite (98), because a given quantity of chlorine can be produced, not only with a less weight of it than of any other ore, but also with a smaller expenditure of hydrochloric acid. Hence ores are valued according to the percentage of available peroxide they contain, or, to speak more correctly, according to the percentage of peroxide to which the oxide they contain is equivalent for the production of chlorine. The average run of ores met with in commerce contain 60 to 75 per cent. of available peroxide, 70 per cent. ore being taken as the standard.

MANGANESE.*INDIAN.***Burma (99).**

Manganese ore, chiefly psilomelane, occurs on King Island (99) in the Mergui Archipelago, and in Mergui

(99) and Tavoy (99). The specimens hitherto obtained, however, are of poor quality.

Afghanistan (99).

In the hill of Bakkarkanch, near Thal, in Afghánistán, oxide of manganese (99) occurs in small quantity, and is used as 'kohl' for application to the eyes.

Central Provinces (99).

Manganese ore, some of which is of excellent quality, occurs abundantly in some parts of the Central Provinces. At Gosalpur, in the Jabalpur District, psilomelane (99) is found in irregular masses through a thick band of maniferous iron ore, which has been traced for a considerable distance, and which there is reason to believe extends much further. If the iron ore were worked, a good deal of psilomelane would be raised at the same time. An assay of the latter gave 83·2 per cent. of available peroxide.

At the same place pyrolusite (99) occurs in nodules forming an irregular bed in laterite. There is probably a considerable amount of the ore obtainable. It yielded on assay 83·0 per cent. of available peroxide, or the same quantity as the psilomelane, but, being a softer ore, it would be more easily acted on by acid. Both are of high quality. The pyrolusite has been used to a trifling extent by glass-workers at Murwára, in the northern part of the district.

A band, some 10 feet thick, of braunite, has been traced for a quarter of a mile near the town of Rámtek (99), 20 miles north-east of Nágpur. The mineral when examined gave 52·8 per cent. of available peroxide, being, like all braunite, a very low grade ore.

A similar ore occurs at Kodaigowan (99), 20 miles north-north-west of Nágpur, but nothing is known as to its quantity.

Very recently manganese has been found, apparently in large quantity, at Burha (99), in the Balaghát district. The ore is a mixture of braunite and psilomelane. The sample assayed gave 71·2 per cent. of available peroxide being therefore of fair average quality.

Haiderabad (99).

Manganese has also been found at Pimpul Khunta (99), in Haiderabad (Deccan), under doubtful circum-

stances. A very impure psilomelane occurs in botryoidal masses in Kámthi clays at Malágarh hill (99), in the Wun district of Berár.

Specimens from several other localities (99) are included in the collection, but the ore does not occur in such quantity, or of such quality, as to necessitate special notice.

IRON.

INDIAN.

Iron ores are widely distributed over India, and in many provinces enormous deposits, often of great thickness and purity, occur. Some portions of India, indeed, can well bear comparison with any part of the world in respect to the abundance and quality of their resources in this respect. The ores are as widely distributed geologically as geographically, occurring in numerous formations, from the oldest crystalline rocks, at one end of the scale, to the most recent detrital deposits at the other. Taken as a whole, the iron ores of India are bedded rocks, although vein deposits also occur. The formations in which iron ore is more especially abundant are the metamorphic strata, the ores in which are generally magnetite¹ and hematite; the sub-metamorphic or transition series, the mass of the ore in which is hematite, although magnetite also occurs; the ironstone-shale group of the Lower Gondwánas, in the Damuda Valley, which contains a large proportion of clay-ironstone, often altered near the surface to earthy limonite and hematite; some of the tertiary strata, the ore in which is most commonly limonite; and the laterite formation, all of which is highly ferruginous, and many parts of which constitute a good or rich ore, the great bulk of which is limonite.

In former times the manufacture of iron by native methods was widely practised throughout the various provinces of India, but within the last few decades, and more especially during the last 20 years, since the opening of railway communications, the competition of English iron has done much to curtail, and in many cases to entirely extinguish, the native outturn.

¹ For descriptions of the different varieties of iron ores see *Foreign Iron*, p. 70.

Even now, however, iron is made in numerous districts, the method adopted being, with some exceptions, very similar over the whole of India. The furnace, built of clay, is generally some 3 or 4 feet in height, more or less, the blast being supplied through clay tuyeres from two skin bellows worked alternately, so as to keep up a continuous stream of air. The fuel used is charcoal, and no flux is added with the ore. At the end of the operation a bloom of malleable iron is obtained, which is refined by reheating and hammering. The expenditure of charcoal is very great, and a large quantity of iron remains in the slag, so that the process is a very wasteful one. At the same time the iron obtained is generally of very good quality.

Several attempts have been made to manufacture iron on the English principle in India, but from various causes none of these have been successful. In some cases the failure has arisen from the difficulty in keeping large furnaces supplied with charcoal, in others from the inferiority of the coal procurable, and in the latest attempt from the underselling of the Indian-made pig-iron by that imported from England.

Burma (100).

Iron ore has been found in the Andaman Islands (100) and the Mergui Archipelago (100), and it is abundant in parts of Mergui (100) and Tavoy (100), where limonite and magnetite occur.

Amongst the ores of Upper Burma are specular and micaceous iron (100). The principal site of iron manufactures in Upper Burma is the neighbourhood of Puppa, an extinct volcano. The furnaces are remarkable from being worked without artificial blast. The ore is limonite obtained from upper tertiary gravels, and from the iron 'dhas' (100), and other implements are made.

Manipur (100).

At Kokshing, and other places in Manipur, a layer in the alluvium, occurring a few feet below the surface, is utilized as a source of iron (100). The clay (100), which contains small pisolitic nodules of limonite, is washed to separate the latter (100), which are afterwards pounded and smelted. The furnaces are peculiar in having two orifices opposite the tuyeres, so that the blast passes

across the hearth of the furnaces instead of ascending the chimney, which is only used for feeding in the fuel and ore.

Assam (100, 101).

Iron used to be made in the Khási-Jaintia hills, but the manufacture is now quite extinct. The ore employed was a titaniferous magnetite (100) occurring in the form of minute grains disseminated through decomposed granite. The soft friable rock was raked into a narrow channel with a rapid current of water running down it, and the heavy iron sand (100), caught by a small dam, while the lighter particles were washed away. The ore thus partially washed was then removed to troughs with a current running through them, and further purified by re-washing (100). After smelting, the crude iron first obtained (100, half of a bloom) was refined (100) more than once by reheating and hammering. Three and half seers of the crude material yielded two seers of refined iron. The quality of the latter was excellent, and the iron suitable for all such purposes as Swedish iron is used for.

Iron (100) was also made in Upper Assam from magnetic iron sand (100).

Impure limonite occurs plentifully in the Siválik strata of Upper Assam (100, Sibságar district), but the ore is of poor quality.

In former times nodules of clay-ironstone (101, Dikhu and Saffrai Valleys), occurring in the coal-measures of Upper Assam, were smelted for iron (101, Jaipur), and during the most flourishing period the outturn must have been very considerable. As long ago as 1841 the manufacture was all but extinct, and has for many years been wholly so.

Bengal (101—104).

A valuable bed of magnetite (101) with micaceous hematite (101) occurring at Sikbhar, in the Dárjiling district, has been worked to some extent. The former ore gave on assay 71.5 per cent. of iron, with no phosphorus or sulphur. From the ease with which it is crumbled down into grains, it is well adapted to the native furnaces, and the smelters assert that it yields a steely iron (101) suitable for kukris and knives (101).

Magnetite (I01) and hematite (I01) have been found in some other parts of the district, and at Lohárgarh hill there is a strong band of limonite (I01) in the Siválik strata. The last-named ore only contains some 30 per cent. of iron.

The ores of Sháhabad (I01) and Patna (I01) do not require any special notice. Iron has been smelted in the Bhágalpur district. According to the usual practice in most parts of India, the bloom is cut nearly (I01) or quite (I01) in two immediately after removal from the smelting furnace, the object being, in part at least, to show purchasers the quality of the iron.

In Birbhum, iron used to be made on a comparatively large scale, the *kacha*, or crude iron (I01), unlike that produced in other parts of India, resembling pig-iron, from which *pakka*, or refined iron (I01), was produced by a sort of puddling process. More than one attempt has been made to conduct iron-smelting on the European system in Birbhum, and about 1855 the Birbhum Iron-Works Company commenced operations at Mahámad Bazár. The ore used (I01), which contained, on an average, over 40 per cent. of iron, was from beds near the base of the laterite, the fuel being charcoal, and grey (I01) and white (I01) pig-iron were produced, which were reported to be superior to ordinary English pig. But, from various causes, the works were financially a failure.

In the Rániganj coal-field, throughout the 'ironstone shale' group, alluded to in connection with coal,¹ but more specially in the upper part of the group, bands of clay-ironstone are common, and constitute an inexhaustible supply of ore. When unaltered, the ore is either clay-ironstone (I02), or black band (a carbonaceous variety of the same, I02), but near the surface it has been converted into earthy hematite (I02), or limonite (I02), or a mixture of both (I02). The ores (of which numerous samples are included in case I02) generally contain from 20 to over 50 per cent. of iron, the average being about 40. The amount of phosphoric acid varies from .1 to over 2 per cent. The above were the ores used by the Bengal Iron Works, which were started at Barákar in 1874 and ceased operations five

¹ P. 28.

years later. Twelve thousand seven hundred tons of pig-iron (I02) were produced, with coke as fuel, during the time the works were open; the analysis of three samples showed from 1.36 to 2.30 per cent. of phosphorus. At first the iron cost in production Rs. 65 per ton, while English pig-iron was selling in Calcutta at Rs. 60. Within two years the cost at Barákar was reduced to Rs. 40, but English pig-iron was quoted at Rs. 29, so that the Company, being unable to produce their iron at a lower figure, were obliged to close the works.

A little outside the limits of the Rániganj coal-field, near Behárinath (I03) and Panchét (I03) hills, some rich deposits of magnetic iron occur in the metamorphic strata. From the degradation of such ore magnetic iron sand (I03) is produced. Ilmenite, or titaniferous iron, has been found in the Mánbhum district (I03). Amongst the ores of Singbhum (I03) is a mangani ferous limonite (I03) occurring near Chaibása.

Clay-ironstone (I03) and the same ore in an altered state (I03) are met with in the Tálchir coal-field. At Sassamora a mangani ferous iron ore (I03) has been smelted, and iron (I03) has been produced from a highly ferruginous sandstone (I03) at Bungáru; a similar ore (I03) has been smelted for iron (I03) at Kankarai in Kattak.

Magnetite (I03) and magnetic iron sand (I03) are found near Karharbári, in the Hazáribágh district, and the latter has been smelted for iron (I03).

Clay-ironstone is by no means so abundant in the coal-fields of the Upper Damuda Valley as it is in the Rániganj field, although it still occurs in some quantity in places. As usual, that found near the surface is altered to earthy hematite or limonite. In the Káranpura field the ore (I04) has been smelted for iron (I04). It also occurs in the Auranga (I04), Hutar (I04), Daltonganj (I04) and Tatapáni (I04) coal-fields, especially in the first named. Magnetite exists, but apparently not in very large quantity, in the Palamow Sub-Division (I04). A lateritic ore has been smelted on the Dudhia Pát (I04), in Lohardugga.

A rather large deposit of magnetite has been found in the Barábár hills (I04) in the Gaya district; it has not been worked, although iron (I04) has been made in the district from other ore.

North-Western Provinces (105).

At Korchi, in South Mirzapur, a magnetic ore (105) has been smelted on a trifling scale, the iron produced (105) being worked up into kulháris (105), &c.

In several parts of Kumáun deposits of iron ore occur, some of which are rich and abundant. Amongst the localities which have attracted most notice is Rámgarh, near which several mines have been worked in micaceous iron (105) and limonite. Hematite and micaceous iron have also been raised near Khairna (105), but the deposits are not of much importance. Very large quantities of ore, which is earthy hematite and limonite, occur in beds in the Sivalik strata, in the neighbourhood of Káladhungi (105) and Dechauri (105). The Dechauri ore, which contains on an average about 40 per cent. of iron, is of better average quality than the other.

Several attempts have been made to smelt iron in Kumáun on the English system, and at the Dechauri works some pig-iron (105) has been produced, the fuel used being charcoal; but, owing to various causes, the different schemes have all miscarried.

A considerable number of mines are worked in Garhwál, the ores being micaceous hematite (105), magnetite (105), and limonite, some of which is mangiferous (105).

Punjab (106).

About 3 years ago iron works, belonging to the Rájah of Sirmur, were started at Náhan. The ore used is a granular magnetite found at Chaita (106), about 24 miles distant, and the fuel charcoal.

In Chamba (106), Jammu (106), Lahaul (106), and the Salt Range (106), some ores have been found which do not require special notice. In the Korána hills, south of Sháhpur, iron (106) has been made from hematite (106).

Rajputana (106).

Iron is smelted in several parts of Rájputána. Amongst the ores worked may be mentioned limonite from Barundni (106), Gangar (106), and Etawa (106; also iron produced therefrom, 106), in Udaipur or Mevár; earthy hematite from Bharampura (106), near Bundi; magnetite from Raido (106), and ferruginous

schist from Bhángarh (106), in Alwar; hematite, with magnetite, from the Biána hills (106), in Bhartpur; and schistose hematite from near Dosa (106), in Jaipur.

At the Khetri and Singhána copper mines, in Jaipur, *kasis* (106), which is a mixture of ferrous and ferric sulphates, is produced, together with alum and sulphate of copper, by lixiviating pyritous shales, and evaporating the solution. The *kasis* apparently is obtained from the mother liquor after the other salts have crystallized out.¹

Central India (106).

Very rich deposits of iron occur in the hilly country to the south of Gwálor, which were formerly much more extensively worked than now, the falling off being caused in part by the growing scarcity of fuel. Amongst the principal mines open in 1870 were those at Mangor (106) and Pár hill (106), the ore raised being schistose hematite. At Kharia (106), and other places, a harder ore is found, but is not worked on account of its being more difficult to mine and smelt.

Iron is also very plentiful in the Bijáwar rocks of Bandelkhand. The ore, which is hematite, is worked amongst other places near Sháhgarh (106), Bijáwar (106), and Hirapur (106). At the last-named town iron is made rather largely, part of which is worked up into *táwas* (106), or shallow basins for cooking chupáttis.

The same rocks are met with in the Narbada valley near Harda and Barwai, and there also contain large quantities of iron. The ore is mainly hematite (106), specular iron (106), and limonite (106); magnetite (106) also occurs, but perhaps not in the same beds. About 20 years ago iron-smelting works were constructed at Barwai for the reduction of the above ores, but when the preparations were nearly complete, it was decided to abandon the project.

Central Provinces (107 to 109).

Iron exists in immense quantities in the Jabalpur district, both in the Bijáwar, or transition, rocks and in the laterite. The ore in the older series is mainly hematite, in part manganiferous, although magnetite and limonite occur more exceptionally; that in the lateritic formation is limonite.

¹ p 54.

The Bijáwar ores are worked in several places, and iron is still smelted on a somewhat considerable scale in the district. Gangai (107) is, perhaps, the only spot where magnetite is raised. At Agaria (107) and Pertábpur (107) there are whole hills of schistose and micaceous hematite, fair samples of which yielded on assay 65 per cent., or more, of iron with about .1 per cent. of phosphoric acid, and only traces of sulphur. The micaceous variety is mined, in preference to the other, from being softer. The Jauli mine (107 and under 109), however, is the most extensively worked in the district; the ore, being an ochreous hematite, is easily extracted, and probably has been found by experience to be easy of reduction. From the crude Jauli iron (under 109) good bar iron (107) has been experimentally made. Olphert's metallic paint (107) is made from the Jauli ore by grinding it to an impalpable powder.

At Mangeli (under 109), Mogala (107), Gogra (108) and Danwai (108). in the Lora ridge, a manganiferous hematite is worked, the iron produced therefrom (107 and under 109) being a hard steely kind used for edged tools. The iron smelted from the Agaria, Pertabpur and Jauli ore is much softer. The Gogra ore was found to contain about 46 per cent. of iron and 12 of manganese; a similar ore occurs in large quantity at Gosalpur (108) and limonite (108) also.

The laterite ores are found in beds near the bottom of the formation. There are two principal varieties: a pisolitic or oolitic limonite, breaking with a conchoidal fracture, like that from Bijori (107, 108 and under 109), &c., and a pisolitic rock, breaking with a rough uneven fracture, like that of Emelia (108). The Kanhwára hills (108, Piprehta) are especially rich in such ores, the estimated quantity in an area of $2\frac{1}{2}$ square miles being nearly 50 million tons. The laterite ores generally contain about 55 per cent. of iron and more phosphorus than the hematites. Of the samples assayed, the former gave phosphoric acid .76 to 1.41 per cent., the latter .07 to .27. The laterite ore used to be smelted (108 and under 109) on a considerable scale, but of late years the mines have been abandoned.

If the Umeria coal-field¹ should turn out as well as

¹ p 31.

there is reason to expect, the Jabalpur district will present exceptional advantages for the smelting of iron on the English principle. There is, perhaps, no part of India in which abundant and excellent ores, pure flux, and good coal, are to be found together in a similar area.

Tendukhera, in the Narsinghpur district, has long attracted notice owing to the excellent quality of the iron (109) manufactured there, which is said to command a higher price than any other iron made in the Narbada valley. In 1830 a suspension bridge over the Bias river, in Sagar, was opened, the iron for which had all been smelted in native furnaces at Tendukhera. The ore is an earthy manganiferous hematite and limonite (109), and the good quality of the iron has been attributed to the ore being somewhat calcareous (the gangue being partly limestone), which produces the same effect as would a purposely added flux. The quality may also be due, in part, to the manganiferous character of the ore. It appears that part of the iron produced is converted into steel. The hematite of the Lora ridge in Jabalpur¹ is another instance of manganiferous ore being used for making steel, or steely iron.

The ores of the Dumoh district (109) scarcely require notice.

Very rich iron ores occur in remarkable abundance in the Chánda district. The ore is mostly hematite (109), but magnetite (109) and limonite (109) also occur. Amongst other important localities are Mendki (109), Lohára and Ratnapur (109). At Lohára there is a whole hill of iron ore, a sample of which contained about 69 per cent. of iron, .012 of sulphur and only .005 of phosphorus. About eight years ago an experimental attempt was made to produce iron on the English system from the Chánda ore, which failed mainly owing to the indifferent character of the Warora coal.²

In the Raigarh and Hingir coal-fields, some ironstone (109) occurs, which is smelted (109) to some extent. At Katterbagga in Sambalpur, iron (109) used to be made from earthy hematite (109) and limonite (109).

Haiderabad (109).

At Yenák hill pebbles of hematite (109) are scattered

¹ p 67.

² p 31.

through sandstone, and where the latter has weathered away, loose heaps of ore are found loose on the surface. Iron has been smelted at Hunamkunda from hematite (I09), and earthy limonite (I09) occurs at the same place.

Bombay (III).

Hematite (III) and limonite (III) ores occur in several parts of Kachh (III) and Kathiawár (III.) Some of them were formerly smelted, but, owing to the competition of English iron, the native industry is now extinct. Most of the laterite of Belgaum (III) and Kaládghi (III) is scarcely rich enough in iron to be considered an ore, although good ore occurs in places and was formerly smelted. In the latter district schistose hematite (III) occurs at Amingarh hill. Micaceous iron has been found at Malwan (III) in Ratnagiri.

Madras (II2).

Amongst the ores of the Kistna district is a limonite, mixed with the uncommon ore turgite (II2), which occurs at Jaggiapett. Iron ores are abundant in the Kadapah district, hematite (II2) being included amongst them, and the metal is smelted from them on a considerable scale. Hematite also occurs at the Sandur hills (II2) in Bellary.

The Salem district has long been celebrated for its enormous deposits of magnetite (II2). Numerous beds, some of great thickness, have been traced for long distances, and the quantity of ore available must be estimated at thousands of millions of tons. The magnetite occurs in association with quartz rock, the two rocks being interbanded. In the best ore (II2) the proportion of quartz is small; in the poorer (II2), crystals of magnetite occur thickly disseminated through a quartzitic matrix. From the degradation of these rocks magnetic iron sand (II2) is produced. Excellent iron (II2) used to be, and still is, smelted from the above ores, but the outturn is decreasing, owing to the competition with English iron and the increasing scarcity of charcoal. The magnetite is separated from the quartz by stamping the ore, and either washing it in a current of water or winnowing it in the manner in which rice is separated from the husk.

It is from the iron just mentioned that the 'wootz' steel (II2) of Southern India is made. The iron

hammered out into bars (II2), which are cut into small pieces to allow of their being packed close in the crucible. A number of these pieces, weighing from half a pound to two pounds, are put into a crucible (II2), with a tenth part, by weight, of dried wood, chopped small, and covered over with one or two green leaves; the mouth of the crucible is then filled up with tempered clay, rammed in close. As soon as this clay is dry, from 20 to 24 crucibles are built up in the form of a low dome in a small furnace, after which the blast is kept up for about $2\frac{1}{2}$ hours. The crucibles are then removed, allowed to cool, broken, and the cakes of steel (II2), which have the form of the bottom of the crucibles, taken out. When the fusion has been perfect, the top of the cake is covered with striæ (II2), radiating from the centre. The cakes are subsequently heated for several hours in a charcoal fire and hammered out into short bars (II2).

The crucibles (II2) are formed of a refractory sandy clay, mixed with charred rice-husk. The wood which is always used is that of the *Cassia auriculata*, and the leaves those of the *Asclepias gigantea*, or, if such are not procurable, those of the *Convolvulus laurifolius*.

In 1833 a Company, called the Indian Steel, Iron and Chrome Company,¹ was formed, with works near Salem and at Porto Novo. Pig-iron (II2) was smelted from the Salem ore, part of which was sent to England, and commanded a good price for conversion into steel; a large quantity of it was used in the construction of the Britannia and Menai bridges. Excellent steel was also produced at the Indian Works. The Company, however, appears never to have paid a dividend, and the concern was a steadily losing one.

IRON.

FOREIGN.

Ores of Iron (II3).

The most important ores of iron are as follows, the figures indicating the percentage of metal they contain when pure—

Magnetite, or *magnetic iron*, protosesquioxide; 72.4.

Hematite, or *red hematite*, sesquioxide, 70.0.

¹p 58.

Limonite, or *brown hematite*, hydrous sesquioxide, 59.9.

Siderite, or *spathic iron*, carbonate, 48.3.

Clay-ironstone, or *argillaceous iron ore*, which is an impure variety of the carbonate.

Magnetite (II3) very often has a granular structure, on account of which it is easily worn down by atmospheric agencies into magnetic iron sand (I33). It is one of the most important ores, and that from which the finest qualities of steel have been produced.

Hematite occurs under several forms; in crystals, or specular iron (II3), massive (II3), schistose (II3), as micaceous iron (II3), fibrous (II3), oolitic (II3) and ochreous (II3).

Ilmenite, menaccanite, or titaniferous iron (II3) is allied to hematite in composition, but has part of the iron replaced by titanium. It is scarcely used as an ore.

Limonite is mostly fibrous (II3), massive (II3), pisolitic (II3) or ochreous (II3). Hematite and limonite are easily distinguished from each other by the 'streak'—when scratched, the powder of the former is red, of the latter brownish-yellow.

Siderite, or *spathic iron* (II3), frequently contains manganese, and hence is much used in the production of 'spiegeleisen.'¹

Clay-ironstone (II3) is an argillaceous carbonate of iron which is found more especially in the coal measures, where it occurs in nodules and continuous layers. It is frequently worked in conjunction with coal and raised from the same mines. The ore sometimes has a deep brown or black color, owing to its containing a considerable proportion of carbonaceous matter, and is then known as 'black-band.' The greater portion of the iron produced in England is smelted from clay-ironstone, which generally contains between 30 and 40 per cent. of metal.

Manufacture of pig and malleable iron (II4 to II6).

According to the method commonly practised in Europe and America, iron is reduced from its ores in a 'blast furnace,' which is generally from 40 to 80 feet

¹ p 74.

in height; the furnace is charged at the top with a mixture, in the proper proportions, of fuel, ore, and flux, and a strong blast of air is forced in through orifices at the bottom. The fuel used in England is coke and coal. When clay-ironstone is the ore employed it is calcined first, to drive off the carbonic acid and water, and to free it as much as possible from sulphur, the ore at the same time being converted into sesquioxide. The flux commonly employed is limestone, the lime in which combines with the siliceous and aluminous impurities of the ore, forming a fusible 'slag' with them, which floats on the heavier molten iron. The air blown into the furnace is either at the ordinary temperature, or first heated to a temperature of several hundred degrees; the former is spoken of as 'cold-blast,' and the latter as 'hot blast.'

The pig or cast iron thus produced, and which is run out of the furnace at intervals, contains a much larger proportion of carbon than malleable iron. To convert it into the latter it is necessary to eliminate most of the carbon. The pig-iron is first melted in an oxidising atmosphere in a 'refining furnace,' and when the oxidation has proceeded far enough to reduce the percentage of carbon, as well as silicon, to the requisite point, the iron is run out into moulds and cooled with water. The 'refined iron' is then melted with continuous stirring in a reverberatory furnace, with an oxidising atmosphere and having a 'fettling,' or floor of iron oxide; most of the remaining carbon, and the greater portion of the silicon, phosphorus and sulphur, are separated by oxidation, and the iron from the fluid state becomes pasty. The bloom of 'puddled iron' is then removed, and brought under a steam hammer or squeezer, to get rid of the fusible slag, and to weld the iron into a homogeneous mass, which is ready for the rolling mill. In many works the refining process is omitted, and pig-iron is puddled direct.

In case **II4** are samples of the raw materials used in the production of pig-iron at the Gartsherrie Iron Works in Scotland. These include clay-ironstone and blackband, and the same ores calcined, hematite, limestone, and coal.¹ There is also a sample of blast furnace

¹ A sample of the coke produced from this coal is contained in case 84.

slag. In case **II5** are samples of the pig-iron, Nos. 1, 2, 3 and 4, No. 1 being the iron of best quality.

In the same case are samples of the fuel, ore, and flux used at the Lowmoor Iron Works, in Yorkshire, and of pig, refined, puddled, rolled and forged iron. It is unnecessary to describe these in detail as a printed explanation is contained within the case.

Before leaving the subject of iron-smelting, attention may be called to the cyano-nitride of titanium (**II4**), a peculiar copper-colored substance, which is sometimes found in blast furnaces smelting titaniferous ores.

Steel (**II4**, **II6**).

Steel is intermediate in composition between cast and malleable iron, containing less carbon than the former, and more than the latter. Up to some 30 years ago, it was made by the *cementation process* only, which is still in use for the production of steel for cutlery, tools, and other of the finer purposes. According to this process bar (malleable) iron (**II4**) is placed in alternate layers with charcoal or soot in fire-brick boxes, and kept at a full red heat for about seven to ten days, according to the quality of steel that is needed; during this time the iron combines with the requisite amount of carbon. The resulting steel is covered with 'blebs,' or blisters (**II4**), and hence is termed 'blister steel' (**II4**). This is not sufficiently homogeneous for immediate use; the bars are consequently broken into pieces about 16 inches long, and drawn out at a red heat under the hammer. Several bars, thus obtained, are then piled into a faggot, and welded together into one. The steel is then termed 'single shear,' or 'tilted steel,' and after passing through the rolls, 'tilted and rolled steel' (**II4**). By dividing the bar of single shear steel in two, and re-welding, 'double shear steel' (**II4**) is obtained. Homogeneity is also obtained by fusion. When the blister steel has been melted in crucibles (**II4**), it forms 'cast steel' (**II4**).

In case **II6** is a series of specimens illustrating the manufacture of steel, by the *Bessemer process*, at the 'Actien-gesellschaft für Bergbau, Eisen und Stahl Industrie,' in Westphalia. According to this process several tons of melted pig-iron (**II6**) are poured into a large retort-like vessel, formed of wrought-iron plates,

with a highly refractory lining, and air forced in through small orifices at the bottom. The air, in passing up through the molten iron, oxidizes the carbon and silicon, which are eliminated as gas and in the slag, the iron thus changing to malleable iron, which is kept fluid by the heat evolved by the combustion of the impurities. The requisite amount of melted 'spiegeleisen'¹ (II6), a mangiferous cast-iron containing a high percentage of carbon, is then poured in, so as to introduce the amount of carbon necessary to convert the de-carbonized iron into steel. The blast is then turned on again for a few seconds, and the steel poured out into a large ladle, from which it is cast into ingot moulds. The ingots are finally taken to the rolling mills, and rolled into bars (II6), rails (II6), and other forms.

According to the original process, with a siliceous lining to the converter,² the phosphorus and sulphur could not be removed from the iron; hence, it was necessary to use iron produced from hematite (II6) and other ores nearly free from such impurities. By a recent modification, using a 'basic' lining, nearly all the phosphorus and part of the sulphur are eliminated, so that Bessemer steel can now be made from iron of a commoner kind.

Samples of malleable iron from the same works are also included in the case.

More than 160,000 tons of cast and wrought iron, and over 10,000 tons of steel, were imported into India in the year 1882-83, almost the whole of which came from Great Britain.

Ferruginous pigments (II4).

Several pigments of red, yellow, and brown shades consist essentially of anhydrous or hydrous oxide of iron. Amongst these Indian red (II4) and Venetian red (II4) are composed of finely ground hematite. Yellow ochre (II4) is made in the same way from ochreous limonite, often mixed with much clay. Umber (II4) and sienna (II4) are somewhat similar materials; by heating these and driving off the water they contain, burnt umber (II4) and burnt sienna (II4), different in color from the raw substances, are obtained.

¹ p 71.

² p 19.

NICKEL.*INDIAN.*

Somewhat niccoliferous pyrrhotite (magnetic pyrites) is found along with copper pyrites, cobaltite, &c., at the Khetri-Singhána mines (II7), in Jaipur (Rájputána). It is, doubtless, from the decomposition of this pyrrhotite that the nickel found in a sample of mixed salts (II7) from the Singhána alum-works¹ is due.

A ferruginous schist, containing a little nickel (II7), is smelted at Bhángarh, in Alwar, and a niccoliferous iron (II7) produced therefrom.

NICKEL.*FOREIGN.*

Amongst the most important ores of nickel are niccolite (II7) or arsenide, gersdorffite (II7), or arsenosulphide, and garnierite (II7), a niccoliferous magnesian silicate which is found in New Caledonia. From niccoliferous pyrrhotite (II7), which generally contains from 3 to 5 per cent. of nickel, a large proportion of the metal of commerce is obtained.²

In the preparation of the metal, oxide of nickel (II7) is first obtained; this, either in the form of small cubes, or irregular lumps, is subsequently reduced by heating strongly with charcoal. The resulting nickel is not completely fused, so that it is obtained, either in small cubes (II7), or irregular lumps (II7), according to the original form of the oxide.

The most important uses of nickel are in the manufacture of German silver (II7), which is an alloy of copper, nickel and zinc, and for nickel-plating by electro-deposition (II7).

COBALT.*INDIAN.*

In one or two of the copper mines near Khetri, in

¹ p 54.

² A complete series of the ores of nickel is contained in the systematic collection of minerals. See millerite, pyrrhotite, niccolite, case 4; chloanthite, gersdorffite, ullmannite, case 5; garnierite, case 26; annabergite, case 27; zaratite, case 34.

Rájputána, cobaltite, with cobaltiferous arsenical pyrites, occurs in minute crystals disseminated through slate (II7). This rock is pounded up (II7) and used, (after the slaty gangue has been removed by washing), at Jaipur and elsewhere for making blue enamel, and coloring glass bangles: the native name for it is '*sehta*'.

A cobaltiferous ferruginous matt (II7) is imported into India, apparently in some quantity, from Nepál, but nothing is known as to the locality where it is produced.

COBALT.

FOREIGN.

One of the most important ores of cobalt is smaltite (II7), an arsenide of cobalt, nickel and iron: cobalt-bloom (II7), an arsenate, occurs in considerable quantity in some mines.¹ Oxide of cobalt (II7) is largely used for giving a rich blue color to glass, for painting on porcelain and pottery, and for making several pigments, of which the most important is cobalt-blue. Metallic cobalt (II7) is employed on a much more limited scale than nickel.

URANIUM.

FOREIGN.

The principal ore of uranium is pitchblende (II7), an impure oxide; torbernite (II7) is a phosphate of uranium and copper.

Oxide of uranium is employed for painting on porcelain, yielding an orange or a black color, according to the process followed: also for coloring glass, to which it imparts a peculiar greenish-yellow tint.

TITANIUM.

FOREIGN.

Rutile (II7) and titanite (II3) are the most abundant sources of titanium. Rutile is employed in painting on porcelain, and for coloring artificial teeth.

¹ A complete series of the ores of cobalt is included in the systematic collection of minerals: see linnæite, smaltite, cobaltite, danaite, in case 5; asbolite, in case 10; erythrite, or cobalt-bloom, in case 27.

TUNGSTEN.*INDIAN.*

Wolfram¹ (II7) occurs not uncommonly in association with the stream tin of the Malay Peninsula.

TUNGSTEN.*FOREIGN.*

The chief source of tungsten is wolfram (II7), a tungstate of iron and manganese, often found in association with tin ore. From it tungstate of soda is made, which is used to some extent as a mordant in dyeing, and for rendering textile fabrics unflammable.

MOLYBDENUM.*INDIAN.*

Molybdenite occurs at the Máhabágh lead mine¹ (II7) in the Hazáribágh district, and in one or two other parts of Chutia Nágpur, but hitherto it has only been found in small quantity.

MOLYBDENUM.*FOREIGN.*

One or two salts of molybdenum are used in chemical analysis, for the preparation of which molybdenite, or sulphide of molybdenum (II7), is the mineral chiefly employed.

ZINC.*INDIAN.***Bengal and Punjab (II8).**

Blende occurs at the old Báraganda copper mine (II8), and the Máhabágh lead mine (II8), in the Hazáribágh district; at the Sabáthu lead mines (II8); and, in association with stibnite, near the Shigri glacier (II8), in Lahaul. In no case, however, has it been found as yet in more than insignificant quantity.

¹ p. 80.

Rájputána (II8).

Zinc mines were formerly worked at Jáwar in Udepur (Rájputána), which are said to have yielded, at one time, a net revenue of Rs. 2,20,000 a year, but during the great famine of 1812-13 the workings were abandoned, and have remained so ever since. A sample of ore (II8) in the museum consists of carbonate of zinc, with blende, in a quartzose matrix. The ore is said to have been placed in crucibles (II8), or retorts, 8 or 9 inches high and 3 inches diameter, with necks 6 inches long and $\frac{1}{2}$ inch diameter (charcoal or other reducing matter being, doubtless, added at the same time). The mouth being closed, the crucibles were inverted and placed in a charcoal furnace, where they were heated for three or four hours.

Madras (II8).

Specimens of ferruginous carbonate of zinc, with blende and barite (II8), from the Karnul district (Madras), seem to have been obtained from the Baswapur lead mines. The ore does not appear to have been ever utilized.

ZINC.*FOREIGN.***Zinc ores (II8).**

The principal ores of zinc are as follows, with the percentages of metal they contain when pure :—

Smithsonite, or carbonate (II8) ; 52·0.

Calamine, or hydrous silicate (II8) ; 53.

Blende, or sulphide (II8) ; 66·9.

Red zinc ore, or oxide (II8) ; 80·2.

Smelting of zinc (II8).

The first three are the ores from which nearly all the zinc of commerce is prepared. The roasted ore (II8, carbonate), mixed with pounded coal, is placed in fireclay retorts, a number of which are heated together in the same furnace ; when the temperature has risen sufficiently high, the zinc is reduced and volatilized, condensing in a liquid form in the removable necks of the retorts. It is afterwards cast into ingots (II8).

Zinc-white (118).

Oxide of zinc (118) is used as a pigment under the name of 'zinc-white.'

LEAD.*INDIAN.*

Lead ore is widely distributed in India, and in certain parts it would appear to exist in considerable abundance: native mines have been worked in many places, and the ore is still smelted here and there. Some Indian galena contains a high percentage of silver.

Singapore (119).

Galena (119), some rich in silver (119), has been worked at Singapore.

Burma (119).

Lead ore has been found in several parts of Tenasserim, including Mergui (119, galena, containing 12 oz. of silver per ton), King Island (119, antimonial galena, containing about 12 oz. of silver per ton), and Maingay's Island (119, galena) in the Mergui Archipelago, Tavoy (119, galena), the Amherst district (119, carbonate and arsenate of lead), near Maulmain (119, galena and carbonate of lead), and Martaban (119, galena).

Until recent years no serious attempt seems to have been made to work the Tenasserim lead, but the ore of Maulmain is now being mined under European management.

Lead ore has also been found near Tonghu (119, galena and wulfenite, the latter rare); and in Independent Burma, near Ava (119, galena), and Amarapura (119, galena). Galena (119) and carbonate of lead (119) occur in the Shan states, where ore is said to be abundant, and argentiferous lead is smelted there, from which the silver is obtained by a process of cupellation.

Assam (119).

The only part of Assam from which lead has been reported is the Bor Kampti Hills (119, galena).

Bengal (119, 120).

Galena has been found in more than one part of the

Bhágulpur district (119). At Phága a vein has been opened out experimentally, and some rich specimens of galena, with cerussite (119) obtained, assays of which gave 58 and 103 ounces of silver to the ton of lead; but no information is available as to the abundance of the ore.

At Bairuki or Baroki, not far from Deogarh, in the Sántal Parganas, galena with cerussite, purple copper ore, &c., (119) has been found, which yielded about 30 ounces of silver to the ton of lead.

In Mánbhum galena occurs at Silli (119), and ore of the same kind (119) has been found near Dhadka, assays of which yielded from 76 to 119 ounces of silver to the ton of lead.

In 1880 a company was started to work galena, with copper pyrites, &c., (119), which had been discovered at Máhabágh, in the Hazáribágh district. Before much had been done in the way of mining the promoters of the Company absconded, and nothing has been done since. Carbonate of lead has been found loose on the surface at Barhamasia (119) and elsewhere (119) in the same part of the district, but the sources from which the ore originally came have not been discovered.

Galena has been worked near Pelowa (120) and Charchari (120), in Sirguja, but neither mine turned out well.

Specimens of galena have been received from Nepál (120), but nothing is known as to their mode of occurrence.

N. W. Provinces (120).

Galena occurs in several parts of Garhwál (120). Some of the deposits have been worked, but apparently the amount of lead obtained has not been large.

Punjab (120).

In Sirmur and Jaunsar mines have been worked, from which large quantities of ore (120, galena, Tons river) are believed to have been raised.

Lead mining and smelting were carried on in the Simla district under European management, but, as the project has been abandoned, it may be inferred that the undertaking was not a profitable one. At the Sabáthu mine the lode of galena (120) was 2 to 3 feet thick, with barite, and some blende, on either side of it. The

lode at Chapla, (I20, galena) is stated to be 2 feet across. The same ore was worked near Huriapur (I20), and near the junction of the Ussan and Giri rivers (I20).

Galena occurs in several parts of Kulu (I20), the ore in one place being associated with a little pyromorphite (I20). On the further side of the Hampta Pass it has been found at the Shigri glacier (I20), in Lahaul.

Galena from near Marri (I20), from Hazára (I20), and from the Chakmanni Valley (I20) in Afghánistán, do not require special notice.

Rájputána (I20).

The most important deposit of lead ore in the Ajmere district is situated close to the city itself, at the foot of Táragarh hill. The mines were farmed by the Mahrattas for Rs. 5,000 a year, and at a later period, when they were under the direct management of the first Superintendent of Ajmere, the annual outturn is said to have been from 10,000 to 12,000 maunds of lead, which was sold at Rs. 11 per maund. Most of it was bought for the Ajmere magazine, and when the magazine ceased taking the metal, in 1846, the mines were closed. The lead was considered purer and better than that from Europe, but even at Agra it could not compete with the latter in price. The ore, which included both galena (I20) and carbonate of lead (I20), was freed from the gangue by pounding and washing. It was then (according to an account published in 1831, the accuracy of which cannot be vouched for), mixed with an equal weight of fresh cow-dung and made into balls about the size of a pigeon's egg, which were dried in the sun. These balls were subsequently smelted with charcoal in blast-furnaces, about 10 inches in diameter and a yard high, the quantity of metal (I20) produced from each furnace *per diem* being about 2 to 3 cwt.

Some galena (I20) used to be obtained in the zinc mines of Jáwar,¹ in Udepur, a sample of which yielded, on assay, about 10½ ounces of silver to the ton of lead.

Lead mines have been worked, apparently within recent years, in Alwar, the ore being galena (I20, and lead smelted therefrom).

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¹ P. 78.

Central India (I20).

Galena has been found, but not in any quantity, at Seonhra (I20), in Datia, and Bargowa (I20) in Rewah.

Central Provinces (I20).

The same may be said of the same ore from Sleenanabad (I20) in Jabalpur. Mines were formerly worked near Joga in the Hoshangabad district. The deserted pits are locally known as the *Chándi khadán*, or silver mines, probably from the glittering appearance of the galena (I20), although it is possible that silver was extracted from the lead. A sample of the ore yielded on assay 21 oz. of the precious metal to the ton of lead.

Some years ago a lode containing galena with cerussite (I20) and having a width of 16 to 19 inches was laid bare near Jhunan, in Sambalpur, and the ore was found to yield about 12 oz. of silver to the ton of lead.

Madras (I20).

At a former period extensive lead mines were worked in the Kadapah district, but they have been deserted for a very long time, and the sites are now overgrown with jungle. The ore (galena, I20) is believed to exist in considerable, perhaps large, quantity, and to be rich in silver.

LEAD.*FOREIGN.***Lead ores (I2I).**

The following are the principal ores of lead, with the percentages of metal they contain when pure :

Galena, or sulphide ; 86·6

Cerussite, white lead ore, or carbonate ; 77·5

Anglesite, or sulphate ; 68·3

Pyromorphite, or phosphate ; 75·5

Galena (I2I) is the ore from which the lead of commerce is almost wholly derived, the amount produced from cerussite (I2I), anglesite (I2I) and pyromorphite (I2I) being comparatively insignificant. Amongst the rarer minerals containing lead are wulfenite, or molybdate (I2I), bindheimite, or antimonate (I2I), and crocoite, or chromate (I2I).

Smelting of lead (I22).

Lead is smelted in several different ways. By the air reduction process, or method by double decomposition, the galena (I22) is roasted in a reverberatory furnace until a portion of it is converted into oxide and sulphate of lead; the temperature is then raised, when these compounds, re-acting on the undecomposed sulphide, produce metallic lead and sulphurous acid.

A considerable amount of lead is volatilized from the furnaces, chiefly as sulphate and oxide; this 'lead fume' (I22) is condensed in long flues, collected from time to time, and subjected to reduction.

According to another process the galena is reduced with metallic iron, the result being lead and sulphide of iron.

The metal, as obtained from the smelting furnace, frequently contains antimony and other metals; such 'hard lead' (I22) is purified and softened (I22) by melting and partially oxidizing the metal in a reverberatory furnace, with a cast-iron bottom.

Desilverization of lead (I22).

All galena is more or less argentiferous, sometimes containing 100 ounces of silver, or more, to the ton of lead. According to Pattinson's process for the extraction of the silver the lead is melted in a large cast-iron pot and allowed to cool down; as it cools crystals (I22) of pure lead form, which, together with some silver mechanically mixed with them, are removed by a perforated ladle to another similar pot, the lead which remains in the first pot (I22) containing most of the silver. By repeating the above process several times in a series of pots the portion of lead poor in silver is rendered poorer and poorer until it only contains a few dwts. to the ton (I22, market lead), while the lead rich in silver is rendered richer and richer until it contains 500 to 700 oz. (I22). Finally the rich lead is subjected to cupellation, *i.e.*, it is kept melted in a 'test,' or cupel of bone ash, and almost completely oxidized by a blast of air; the resulting litharge (I22) flows off in a melted state, and lead extremely rich in silver remains. By a second cupellation pure silver is obtained from the latter; the litharge in this second process (I22) carries a good deal of silver

with it, and consequently requires re-treatment. The old tests are saturated with litharge, and also contain some silver; they are, consequently, broken up (I22) and the metals extracted from them.

Litharge and lead pigments (I22).

Litharge, obtained as above described (I22), when ground is known as flake litharge (I22). It is used as an ingredient of flint-glass, in the preparation of drying oils, and for other purposes.

Red lead (I22) is prepared by first oxidizing lead in a reverberatory furnace, grinding and levigating the 'massicot' thus produced, and further oxidizing the latter in another reverberatory furnace; the red lead resulting from the second operation is finally prepared for use by grinding and levigation. It is largely used as a pigment and in the manufacture of flint-glass.¹ Carbonate of lead may be used instead of massicot for conversion into red lead; when the temperature is properly regulated a pigment of a somewhat different shade, known as orange lead (I22), is obtained.

White lead (I22).

In the manufacture of white lead (which is a basic carbonate), according to the Dutch method, the metal is cast into 'crates' (I22), in forms which present a large surface; these, either in their original flat form (I22), or rolled up (I22), are placed over pots containing vinegar. The pots are embedded in fermenting tan, the temperature of which varies from 140° to 150° F. The vinegar slowly evaporates and attacks the lead, with formation of basic lead acetate, which, in contact with the carbonic acid evolved from the tan, changes to basic carbonate. After some weeks the greater portion of the lead has been converted into white lead (I22); the latter is then detached from the remaining metal and prepared by grinding and washing (I22).

TIN.

INDIAN.

One of the most important tin-producing regions of the world is the Malay peninsula, and the continuation of

¹ P. 21.

the same line of elevation in the islands of Banca and Billiton. Throughout the peninsula the tinstone is found under similar circumstances. The original matrix is granite, and the ore seems to be most abundant near the lines of junction of the granite with the highly metamorphosed slates, &c., with which it comes in contact. The above rocks form the backbone of the mountain range which traverses the peninsula, and through their denudation, and transport to lower levels, have been formed the tin-bearing detrital strata found along the coastal region. It is the latter deposits alone that have been worked, all the metal smelted being derived from 'stream-tin.' No attempt has yet been made to mine the stanniferous parts of the granite.

Southern part of Malay Peninsula (I23).

One of the chief centres of the industry is Larut, in the State of Perak, where numerous stream-works are carried on with Chinese capital and labour. A series of specimens in the collection, including stanniferous granitic pebbles from very high altitudes in the mountains (I23), very coarse stream-tin found at heights of 2,000 to 3,000 feet (I23), coarse stream-tin occurring at elevations of 1,000 to 2,000 feet (I23), and fine stream-tin, or tin-sand (I23), found in the alluvial flat between the mountain range and the sea, show well the decreasing size of the fragments or grains of ore as they are found further and further from their original home.

The stanniferous alluvial stratum at Larut varies from 2 to 8 feet in thickness and is found at a depth of from 4 to 25 feet below the surface. The 'tin-dirt' is washed in wooden sluice boxes, or long inclinal troughs, with cross pieces like dams to catch the tin-sand. The yield of the latter varies from 1 to 2 per cent. of the tin-dirt. The ore is smelted in small furnaces of brick, lined with clay, the blast being supplied by a horizontal wooden blowing cylinder, having a diameter of about 14 inches; at each end there is a clack-valve which admits air, and closes on the return stroke of the piston; the stroke of the latter is about 12 feet, the motive power being three coolies who grasp a cross-piece on the piston-rod. The fuel used is charcoal, and no flux is employed. The tray (I23) in which the specimens alluded to above are contained is made of tin smelted at Larut.

Tin ore is also worked in Salangore (I23), Srime-nauti (I23), and Kopali (I23).

Tenasserim (I23, I24).

Within the limits of the Indian Empire there are extensive and valuable deposits of tin ore in Tenasserim. In former times these were largely worked, and are still on a smaller scale. Amongst the places in the Mergui District where tinstone has been found, and in most cases worked, are Maleewoon (I23), on a branch of the Pakchan river, and the Bhenong (I23), another tributary of the same stream. The reduced tin is cast partly into small ingots (I23), but chiefly into much larger ones for exportation. Bokpyen (I23) is another centre from the neighbourhood of which a considerable amount of metal is annually sent. Stream-tin is also obtained on the Khamoungtang (I33) and the Thabawlick (I23), tributaries of the Little Tenasserim river, and the Thengdau (I23), a branch of the Great Tenasserim river. The ore worked near Yahmon hill (I23) is depreciated in value by admixture with wolfram, a mineral which occurs in other parts, also, of the peninsula. Some ore (I24) has been experimentally obtained from a decomposed highly felspathic stanniferous granite at Kahan hill (I24), near Mergui, but the deposit does not appear to have been regularly worked.

In the Tavoy district stream-tin has been worked at Oungbengwen (I24), Henzai (I24), and Khamoung (I24), and the metal (I24) smelted therefrom.

The ore is also smelted in the Karen hills east of Toung-ngu (I24). Ladles of bamboo (I24) are used for ladling the melted tin, which is cast into ingots (I24) by pouring it into the hollows of split bamboos.

Bengal (I24).

The deposits of tin that have been found hitherto in India beyond the limits of Tenasserim are of but trifling importance.

Near the village of Leda, 8 miles west of the Karharbári coal field, in the Hazáribágh district, tinstone (I24) has been found disseminated through gneiss. The ore was formerly worked on a small scale, first by natives, and subsequently by a European, and some tin (I24) smelted from it. The pit is said to have

been abandoned, partly owing to a decreasing quantity of ore in the rock, and partly owing to the influx of water.

At Pihra, in the same district, tinstone (I24) has been observed in small quantity, in lepidolite granite.

Bombay (I24).

A small sample of tinstone (I24) has been received from near Jambughora, in Guzerát, but nothing is known as to the mode of occurrence of the ore.

TIN.

FOREIGN.

Tin ore (I25).

The ore from which all the tin of commerce is produced is cassiterite, tinstone, or dioxide of tin (I25), which contains, when pure, 78·7 per cent. of metal 'Mine-tin' (I25) is the ore obtained direct from the stanniferous lodes or deposits, which generally occur in connection with granite; stream-tin (I25) is found in alluvial strata derived from the denudation of tin-bearing rocks. Stream-tin, having been naturally freed from sulphides, &c., which often occur in association with mine-tin, is generally purer than the latter, and is used for making the best quality of metallic tin. 'Wood-tin' (I25) is a radiate fibrous variety of tinstone, bearing some little resemblance to wood in appearance.

Bell-metal ore or tin pyrites (I25), a sulphide of tin, copper and iron, containing 27 per cent. of tin, is a rare ore of little importance.

Dressing of tin ore (I25).

The dressing of tin ore, especially mine-tin, preparatory to smelting, generally involves a rather complicated series of operations, owing to the difficulty of freeing it from the various other minerals with which it is at times associated. The ore from the mine (I25), after 'spalling' or breaking-up with hammers, if necessary, and picking, is reduced to powder beneath heavy stamps. The powdered ore from the stamp-grates (I25) is then freed from the lighter impurities (quartz, &c., &c.) by washing on 'buddles,' the ore being generally subjected to this operation twice. The buddled ore (I25)

still retains most of the iron and copper pyrites, arsenical pyrites, &c., which have originally been mixed with it. It is, consequently, roasted in a reverberatory furnace, by which means the sulphides are converted into oxides and sulphates. The calcined ore (I25) is then buddled twice again, in order to remove the oxides and sulphates mechanically or in solution. The ore from the buddles (I25) is placed in a large 'kieve' or tub, well stirred up with water, and allowed to settle; after the water has been poured off, nearly all remaining impurity is found at the top and scraped off, while clean 'black-tin' (I25), ready for smelting, remains below.

'Crop-tin' (I25) includes the chief portion of the ore, which is separated from its waste in the principal dressing operations: the finer portions of ore, which are carried away with the waste, are called 'slime-tin' (I25), which is recovered by a subsequent series of washings.

Smelting of tin (I25).

The 'black-tin' (I25) is mixed with one-fifth of its weight of anthracite, and smelted in a reverberatory furnace; at the end of some hours the reduced metal is tapped and cast into moulds. The impure tin thus obtained is refined by a process of liquation; the ingots are placed in another reverberatory furnace, which is gradually heated, so that the more easily fusible tin melts first and runs into a vessel below, while the impurities (chiefly iron and arsenic), with some tin, remain on the hearth. This alloy, known as 'hard-head' (I25) is afterwards re-treated. The tin is kept melted, and stirred up with a pole of green wood; the gases disengaged from the wood cause the tin to boil up, and a scum, containing most of the remaining impurities, forms on the surface and is skimmed off from time to time.

The whole of the tin of commerce is subjected to this refining process, although the different qualities are known as common (I25), refined (I25), and grain tin (I25), the difference being that the refined tin is made from the best ores, and boiled longer in the refining process than common tin; while for the production of grain tin the finest ingots are heated just below their melting point, and allowed to fall from a considerable height, when the metal breaks up into a granulated form.

After the tin has been run out from the first reverberatory furnace, a scoriaceous mass, containing grains of tin (I25), remains on the hearth. This is raked out, stamped (I25), and the tin (I25) separated by washing. The true slag, called by the smelter glass-slag (I25), runs out with the metal on tapping the furnace.

BISMUTH.

FOREIGN.

The principal ore of bismuth, and almost the only source of the metal used in the Arts, is native bismuth (I26), which is sometimes associated with bismuthine or sulphide (I26).

Formerly, the metal was obtained from the ore by 'liquation'; the ore was heated to just the melting point of bismuth, when the latter flowed away, leaving the gangue, and more difficult fusible impurities, behind.

At the present day, however, the ore is subjected to a smelting process, by which the bismuth is extracted much more completely.

Bismuth forms an ingredient of 'fusible metal,' and other alloys used in the Arts, while some of its salts are employed in pharmacy, and in making cosmetics.

ANTIMONY.

INDIAN.

Burma (I26).

Stibnite (gray antimony ore) occurs near Maulmain (I26), and large quantities are said to have been raised at one time, but, as there was no sale for it in Calcutta, operations were discontinued. The metal is imported to a small extent into British Burma from the Shan States, where stibnite (I26) is found. A specimen of the same ore has been obtained from Ava (I26), but no information is available as to its mode of occurrence.

Nepal (I26).

The same remark applies to a sample of gray antimony from the Trisul Ganga Valley (I26), in Nepal.

Punjab (I26).

In the neighbourhood of the Shigri glacier, in Lahaul, several antimonial lodes are known to exist, which all

observers agree in describing as of remarkable richness. According to one account six distinct lodes could be seen, one of which is stated to be 40 feet wide, and to contain 20 feet of stibnite (I26) with some cervantite (I26) and kermesite. Some years ago a project was started for working these veins and shipping the ore, (freed from gangue by fusion), at an estimated cost of £32 per ton, the estimated value in England being £76; but nothing appears to have been actually done. The position of the lodes, on the further side of the Hamta pass, and at an elevation of 13,500 feet, would prevent any mines being worked for more than a few months in the year, and would render the carriage of the ore to the plains difficult and expensive. Notwithstanding these drawbacks, however, the richness of the veins renders them well worth attention.

Madras (I26).

At Yenchapali, near Dumagudiem, in the Godáveri district, some stibnite (I26) is said to have been found at the bottom of a well which was being sunk for water.

ANTIMONY.

FOREIGN.

Ores of antimony (I26).

The chief ore of antimony, and that from which nearly all the metal of commerce is obtained, is stibnite, or gray antimony (I26), a sulphide which, when pure, contains 71·8 per cent. of metal. Associated with it, and resulting from its alteration, are often found cervantite (I26), an oxide, and kermesite (I26), an oxysulphide. Native antimony (I26) occurs in some quantity in some mines.

Smelting of antimony (I26).

Stibnite, being an easily fused mineral, is separated from the gangue by 'liquation,'—the raw ore is heated to the melting point, when the sulphide of antimony (I26) runs off, leaving the stony impurities, &c., behind. The sulphide is reduced to the metallic state, either by roasting and conversion into oxide, and reduction of the oxide with coal or charcoal, or by fusion with metallic iron.

The most important use of antimony is in the production of type metal, which is an alloy of lead and antimony, with or without the addition of tin. Antimony forms an ingredient of some other alloys also, and is used in the preparation of some pharmaceutical compounds.

ARSENIC.

INDIAN.

Bengal (I26).

On the flank of Sampthar hill, in the Dárjiling district, a seam, about 8 inches thick, of arsenical pyrites (I26), with iron and copper pyrites, has been observed. Specimens of similar ore (I26) have been received from one or two other parts of India, but do not require special notice.

N.-W. Provinces (I26).

Orpiment (I26) and realgar (I26) are brought in small quantities to the Bagesar fair by the Bhutias, and are said to be obtained from near Munshiári, in Garhwál.

ARSENIC.

FOREIGN.

Ores of arsenic (I26).

The most important ore of arsenic is mispickel or arsenical pyrites (I26), a compound of arsenic, sulphur and iron, containing 46.0 per cent. of the first-named element. Native arsenic (I26) is comparatively rare.

White arsenic (I26).

White arsenic, or trioxide of arsenic, is prepared from mispickel (I26) by burning the latter in a furnace connected with a long horizontal flue ending in a vertical chimney. The sulphurous fumes pass out of the chimney in a gaseous state, while the white arsenic condenses in the flue, crystallizing (I26) on the roof and falling on the floor as a heavy crystalline powder (I26). The crude material thus obtained, which has a gray color, owing to impurities, is refined (I26) by resublimation. The burnt pyrites (I26), remaining in the furnace, sometimes contains copper and is treated for the extraction of that metal.

White arsenic is used in glass and porcelain manufacture,¹ for the preparation of several pigments, and metallic arsenic, and for other purposes.

Metallic arsenic (126).

Metallic arsenic is produced either by heating mispickel in close retorts, or by reducing white arsenic with charcoal. It is chiefly used for hardening lead, in the manufacture of shot.

Realgar and orpiment (126).

Realgar (126) and orpiment (126), or the disulphide and trisulphide of arsenic, are used as pigments and in the preparation of hides; realgar is also employed in pyrotechny. These compounds, however, as found in commerce, are chiefly of artificial production.

COPPER.

INDIAN.

Copper is a metal of somewhat wide distribution in India, and one which is, or has been, smelted in many parts of the country. The outturn, however, is very trifling, practically all the copper which is consumed in India being imported from abroad.

In many, if not most, cases the ore occurs disseminated through the older rocks themselves, and not in true lodes. The ore most commonly met with is copper pyrites, often with carbonates, &c., near the surface.

Burma (127).

There does not appear to be any record of valuable deposits of copper ore having been found in British Burma, and in the museum collection are merely one or two poor specimens from Tenasserim (127). A rich sample of copper pyrites² (127), with no locality given except 'Burma,' may be from the Independent kingdom.

Manipur (127).

In 1879 an ore consisting of malachite, chrysocolla, cupreous hematite, and sulphide (127) was discovered in

¹ P. 21.

² For descriptions of the different ores of copper, see *Foreign Copper*, p. 100.

the hills bordering the Kubo Valley, in Manipur, and some copper (I27) produced from it.

Bengal (I27, I28).

Numerous small copper mines have been worked in the Himalayas of Baxa (I27), the Dárjiling district (I27), and Independent Sikkim (I27). The ore occurs disseminated through schistose rocks, and, with the exception of some chalcocite (I27), from the Baxa hills, is in every case copper pyrites (I27).

The method of extracting the ore, as in the case of all native mining operations, is extremely primitive; the mines greatly resemble magnified rabbit-holes,—small irregular passages meandering about without any attempt at system or order.

After a preliminary breaking up of the large pieces of ore from the mine, and rejection of the refuse, the picked ore (I27) is broken up small on flat stones, with hammers formed of suitably shaped pieces of quartz, or other hard rock, tied into forked sticks, and afterwards pounded to a coarse powder (I27) with heavier hammers of the same kind. The powder is washed in troughs having a slight incline and made of rough planks fixed on the ground. A small stream of water flows through, which is regulated in quantity by a dam of clay at the upper end. The ore is continually agitated by hand, or with a small basket-work shovel, and moved towards the upper end of the trough, by which means the larger fragments of copper pyrites (I27), and of iron pyrites if the ore be contaminated with it, are collected there, and the lighter stony residue carried lower down. This residue (I27), which still contains some ore, is ground in hand-mills, similar to those used in India for grinding corn, with grinding surfaces formed of slabs of gneiss. It is then re-washed (I27) in the same way as before, and the same operations sometimes repeated (I27) on the residue (I27). The ore from the different washings is then mixed together (I27), and is ready for smelting.

The smelting-furnace is generally built, with some neatness, of refractory clay, but in its ruder form consists merely of a hole dug in the ground, with a low clay rim along the sides and front, and a higher one, or a flat stone, at the back; the inside is plastered with

refractory clay, if that of the ground itself be not sufficiently infusible. The furnace is about 18 inches deep, a foot square at the top, and tapering towards the bottom. When it is dry, small charcoal is filled in to a depth of about a foot, and beaten down by a wooden rammer till a saucer-shaped floor of coarsely powdered charcoal is formed, sufficiently compact to prevent the products of the smelting sinking into it. These protect it from the blast, and it is besides too compact to burn easily. There is no orifice in the lower part of the furnace. Two clay tuyeres dip nearly vertically about 3 inches into it from the top, and are respectively connected with skin bellows by horizontal clay tubes about a yard long.

The furnace, thus prepared, is lighted up with charcoal, and the bellows at each side worked alternately. When at its full heat, the powdered ore (127) is sprinkled in at short intervals, until a sufficient amount of regulus has collected at the bottom of the furnace, covered by the lighter slag. The fuel is then raked away, and the surface of the slag cooled with a wisp of wet straw tied to a stick. The solidified cake is removed and the fresh surface cooled; in this way the slag (127) is taken off in two or three successive cakes, leaving the heavier and more perfectly fluid regulus behind, which is afterwards cooled and extracted. The regulus (127) is powdered and ground, mixed with an equal amount of cow-dung, and made into balls (127) about the size of oranges. After drying, a quantity of these are spread on a layer of charcoal, in a place surrounded by stones, and covered by more charcoal. The whole is then ignited, and the regulus thus roasted with free access of air. The roasted balls (127) are subsequently crumbled down and ground, and the powder (127) sprinkled into the furnace in the same way as the original ore. The slag (127), when the operation is finished, is cooled and removed in cakes, leaving a fluid mass of metallic copper (127) at the bottom of the furnace. The copper thus produced is sold at the rate of Rs. 2-8 per three sírs, which is equal to about 10*l.* a pound. It is still vesicular and brittle (resembling the 'blister copper' of the English smelters), and undergoes a refining process, by refusion, before being wrought into manufactured articles.

In the Bhágalpur district, some malachite with

chrysocolla (227), in a tremolitic matrix, has been found at Bhagmári.

Some excitement was caused about 30 years ago by the discovery of copper and lead ores at Bairuki, in the Deogarh District. The former included purple copper (127) and copper pyrites (127), amongst other kinds, and the ores of both copper and lead were found to contain a small percentage of silver. Some excavations were made along the outcrop, but, as these did not prove the existence of an extensive deposit, the matter was allowed to drop.

Some pieces of native copper (127) are said to have been found in the sand on the bank of the Damuda river, 6 miles above Rániganj.

In the Máhabágh lead mine, in the Hazáribágh district, purple copper (127) and copper pyrites (127) accompany the lead ore, in a matrix of coccolite and garnet.

The remains of extensive excavations for copper are still to be seen at Báraganda, in the same district. They extend along a line of outcrop of metamorphic rocks, which form a ridge about three quarters of a mile long, the width of the excavations averaging 25 to 30 yards. The name of the place is said to be derived from báraganda (twelve fours), in allusion to the number of old mines, and several acres in the vicinity are, it is stated, covered with mounds of copper slag. The ore, which occurs chiefly in quartz (128), but also in schistose rocks (128), is copper pyrites (128) with a little black oxide (128). Galena and blende are associated with it in small quantity. The 'Báraganda Copper Company' are at present carrying on excavations with a view to testing the value of the deposits.

Another old copper mine is situated at Kalianpur (128), in Mánbhum, but nothing beyond stains of copper carbonates (128) is now visible at the surface. Copper appears to have been worked in one or two other parts of Mánbhum also.

"The district of Singbhum and the state of Dhálbhum include within their limits the most widely extended copper deposits at present known to exist in Peninsular India, traces of copper ores, often principally marked by old excavations, being found for a distance of 76 miles, or from the neighbourhood of Lopso, on the frontiers of Lohardaga, to Kameranara, on

those of Midnapur. This deposit appears to exist on a well-defined horizon of the sub-metamorphic or transition rocks, and close to their base. . . . As a rule, the copper ores occur disseminated through the schists, and the underlie of the deposit in general corresponds to that of the including rocks ; but in some places the ores appear to be distributed in lodes. . . . Indications exist of mining and smelting having been carried on in this region from a very early period, and the evidence available points to the Seraks or lay Jains as being the persons who, perhaps 2,000 years ago, initiated the mining."¹

A company was formed to work the Singbhum copper in 1857. "Mining commenced at Landu (I27) and Jamjura (I27), and from 1,200 to 1,300 cwts. of fine ore was turned out monthly. A heavy royalty of Rs. 9,200 yearly to the Rájahs of Seraikela and Dhálbhum, an expensive establishment of Saxon miners and English smelters, the erection of a costly foundry and engine, and other premature and excessive expenditure, led to the dissolution of the company in 1859. In 1862 an effort was made to start another company with a capital of £120,000, but by 1864 its operations had ceased. . . . Copper pyrites (I27) was first struck by the second company at Rájdoha just before operations ceased. All the ore previously obtained had consisted of the carbonates (I28) and oxides and some glance copper (I28), with traces of other rarer ores."² The Jamjura ore (I28) is remarkable from its containing pieces of a peculiar mineral (I28) containing about 94 per cent. of carbon, and which has been considered as mediate between anthracite and graphite. Mines have also been worked at Tamba-dungri (I28, copper pyrites, with carbonate and silicate, &c.), Ukri (I28, malachite), Kodada (I28, chalcocite and malachite), and several other places. Samples of metallic copper (I28) produced from the ores of Jamjura, Ukri, and Kodada, and sheet copper (I28) rolled from the metal produced by the first company mentioned above, are included in the collection.

Nepál (I28).

Copper mines are, it is believed, worked in Nepál.

¹ V. Ball, *Economic Geology*, p. 247.

² *Ibid.*, p. 248.

but no European has been allowed to visit them. There can be little doubt, however, that the methods of mining and smelting are similar to those practised in the Dárjiling District, where the miners are mostly, or all, Nepális. Specimens of copper pyrites (I28) and purple copper (I28) have been received from Nepál, and of an antimonial copper ore (I28) in a quartzose matrix, which is said to occur in considerable quantity near Khát-mándu, and to have been used for making cannon-balls, which flew to pieces when fired.

N.-W. Provinces (I29).

Rolled lumps of copper ore, including chalcocite, copper pyrites, red oxide, &c. (I29), have been obtained from a fissure in the Bijáwar limestone at Sorai, in the Lalitpur district, but the ore has not, of late years, been found *in situ*. The place is said to have once yielded large supplies of copper.

Copper mines have been worked in several parts of Kumáon and Garhwál, and several reports have been written upon them. The opinions expressed have been conflicting; at least one mining engineer formed a high estimate of them, whilst others have not been favourably impressed. About 40 years ago an experimental attempt was made to work some of the mines under a Cornish miner, but the result was not satisfactory and operations were discontinued.

Amongst the mines which have been worked at one time or other are Dhyang Row (I29) and Kurna Nágpur (I29), in Kumáon, and Pokri (I29), Dhanpur (I29), Dhobri (I29), and Kharai (I29), in Garhwál. The chief ores are copper pyrites (I29) and purple copper (I29).

Punjab (I29).

Copper pyrites has been obtained from Chandáni (I29), on the Giri river, in Sirimur, and from near Sabáthu (I29). Amongst many localities in Kulu where ore exists are Kolpni (I29) and Pilan Kota (I29).

Large masses of native copper (I29) have been found in the bed of the lower part of the Zánskár river, in Káshmir, but their source is unknown. The name Zánskár, or Zángskár, is said to be derived from zangs, copper or brass.



In the palæozoic rocks of the Salt range there are certain beds which have been called the 'copper shales,' owing to the presence of small cupriferous nodules containing sulphide, red oxide, and carbonate of copper (I29). The shales nowhere appear to be sufficiently rich in copper to render them of any economic value.

Rájputána (I29).

Copper ore has been worked, in Ajmir, at Rájgarh (I29, malachite and black oxide) and Gugra (I29, malachite and chrysocolla) amongst other places. At Gugra the copper is associated with lead ore.

The copper mines of Khetri and Singhána, in Jaipur, are on an extensive scale, and must have been worked for a very long period. The mode of mining is of the usual primitive kind, and as there is no means of keeping the mines drained except a rude system of baling, some of them have been abandoned on account of their depth and consequent difficulty with water; in others there appears to have been a partial failure of ore. At the present time very few of the mines are open.

The ore is copper pyrites (I29), although specimens, at least, of native copper (I29) have been obtained. The ore as it comes from the mine is picked, broken up small, and reduced to fine powder under heavy hammers. It is then mixed with cow-dung, and made into rolls about four inches long, which are dried in the sun and then roasted in the open air, in a fire of cow-dung cakes. The roasted ore is smelted in a blast-furnace about $3\frac{1}{2}$ feet high and 12 inches diameter, the lower part of which is built of pieces of slag cemented with clay, while the upper part is of fire-clay alone. Near the bottom of the furnace are four openings, three of which are supplied with tuyeres in connection with skin bellows, while the fourth, at a lower level than the others, and which can be opened or closed with a plate of fire-clay, serves for tapping the furnace. After the furnace has been lit and well heated, the roasted ore is gradually introduced, alternately with charcoal and a flux called rít, which is the refuse from old iron furnaces. At each operation five maunds of ore, the same amount of rít and four maunds of charcoal are consumed. The produce varies, the outturn obtained with the poor-

est ore being twenty sírs of crude copper, which in refining is reduced to about one half. This last operation is performed by passing a strong blast of air over the molten metal, which is constantly skimmed.

The cobalt ore of the Khetri mines has been alluded to in a previous section (page 76), and the manufacture of sulphate of copper (I29) from the refuse of the same mines has been briefly described in connection with alum (page 54).

Copper is also worked at Daribo, in Alwar, the mode of smelting being similar to that adopted at the Khetri mines. Specimens of the raw ore, which is copper pyrites (I29), of the picked and pounded ore made into balls with cow-dung (I29), of the roasted balls (I29), and the crude (I29) and refined (I29) copper, are included in the collection. Sulphate of copper (I29) is made from the refuse of the mines.

Central India (I29).

In the same case are some specimens of native copper (I29), which are said to have been obtained from Bardhi, on the River Son, in Rewah, but it is highly improbable that they ever came from there.

Central Provinces (I30).

Traces of gray copper in a gangue of barytes (I30) have been found near Sleemanabad, in the Jabalpur district.

Copper ore was discovered, in 1873, on a small island in the Narbada, near Barman Ghát, in the Narsingpur District, and a quantity, the subsequent sale of which is said to have paid its expenses, was extracted and sent to England. The ore, which includes blue (I30) and green (I30) carbonates, red oxide (I30), and chalcocite (I30), occurs in an argillaceous schist (I30), which is associated with quartzites of the Bijáwar series.

A malachite ore (I30) has been worked at Govindpur, in the Chánda District.

Madras (I30.)

Copper ore has been mined in several places in Nellore, and the existence of extensive ancient excavations, and mounds of copper slag, proves the extent of the early workings. Several attempts have been made

to re-open the mines under European supervision, but none of these have been successful, although very rich ore has been obtained in some places. The ore is said to occur both in the mass of, and in fissures traversing, hornblendic and garnetiferous schists. It consists mainly of chalcocite (I30) and malachite (I30), but chrysocolla (I30) and the rare mineral atacamite (I30) also occur. The malachite from Ganmanipenta (I30) includes a dark-colored impure variety, to which the name 'mysorin' (I30) was given, under the erroneous idea that it was an anhydrous carbonate of copper, and a new species of mineral.

COPPER.

FOREIGN.

Ores of coppers (I31 to I33).

The most important ores of copper are as follows, the figures indicating the percentages of metal they contain when pure :—

Native copper (I31) ; 100·0.

Chalcopyrite or copper pyrites, a sulphide of copper and iron (I31) ; 34·8.

Bornite, purple copper, or variegated copper ore, a sulphite of copper and iron (I32) ; 55·6.

Chalcocite, copper glance or vitreous copper ore, a sulphide of copper (I32) ; 79·8.

Tetrahedrite, gray copper ore or 'fahlerz,' a sulph-antimonite of copper (I32).

Cuprite, red copper ore, or red oxide of copper (I32) ; 88·8.

Melaconite, black copper ore, or black oxide of copper (I32) ; 79·8.

Chrysocolla, a hydrous silicate of copper (I33) of varying composition.

Malachite, or green carbonate of copper (I33) ; 57·4.

Azurite, or blue carbonate of copper (I33) ; 55·2.

Copper pyrites (I31), although containing a lower percentage of copper than other ores, is the most abundant source of the metal, and that most commonly met with. It is that principally used in the English smelting works.

The color of bornite (I32), on a fresh fracture, is between copper-red and pinchbeck-brown, but the mineral speedily acquires a tarnish in which purple tints prevail; hence the names 'purple copper' and 'variegated copper ore.'

The copper in tetrahedrite (I32) is usually replaced in part by other metals, so that the composition varies greatly. The mineral generally contains some silver, and sometimes a large proportion.

The oxides and carbonates of copper (I32, I33) are usually found comparatively near the surface, having been formed through the alteration, by atmospheric agencies, of sulphuretted ores occurring in the unaltered lode beneath. When obtainable in quantity, they are very valuable ores, on account of the high percentage of copper they contain, and the comparative simplicity of the reduction process.

In lodes of copper pyrites the ore near the surface is frequently altered to a cellular oxide of iron, often mixed with quartz, &c., which is termed 'gossan' (I31) by the Cornish miners. It is due to the oxidation of the ore and removal in solution of the copper, probably as sulphate, while the oxide of iron remains behind. The presence of gossan at the surface is looked upon as a valuable indication in searching for metalliferous deposits. As it is often due to the alteration, not of copper but of iron pyrites, which is a common mineral in lodes of various kinds, its presence does not necessarily prove the existence of copper beneath the surface.

Smelting of copper (I33).

As previously remarked, the most abundant ore of copper is copper pyrites; it is that principally used in the smelting works at Swansea, in South Wales. The English process by which it is reduced is a rather complicated one, which is illustrated in the collection by a series of specimens from the Hafod works belonging to Messrs. Vivian and Sons. The ore to be smelted (I33) should be neither too poor nor too rich, but should contain from 9 to 13 per cent. of copper, a proportion which is obtained by a proper admixture of ores. The reduction process usually includes six distinct operations, which are conducted in reverberatory furnaces of two classes, termed respectively calcining and melting furnaces. 1st,

the raw ore (I33) is calcined, one result of which is the elimination of a portion of the sulphur. 2nd, the calcined ore (I33) is melted with slag obtained in the fourth operation and known as metal slag; the products are a regulus consisting of a mixture of the sulphides of copper and iron and called 'coarse metal' (I33) and a slag of silicate of iron called 'ore furnace slag' (I33), which is thrown away. The coarse metal is granulated by letting it flow out of the furnace, in a melted state, into water. 3rd, the granulated coarse metal is calcined in order to eliminate a portion of the sulphur. 4th, the calcined coarse metal (I33) is melted, with the addition of 'roaster' and 'refinery' slags, produced in the two following operations, and oxidized ores (carbonates and oxides); the products are white metal (I33), which is a nearly pure cuprous sulphide, and a slag consisting chiefly of iron silicate with some copper, termed 'metal slag' (I33). 5th, the white metal (I33) is subjected to the operation termed 'roasting'; it is melted and partially oxidised, the oxide of copper reacting on the remaining sulphide, with the production of sulphurous acid and metallic copper. The latter, which contains about 95 per cent. of copper, with some iron, sulphur, &c., is full of cavities, and hence is termed 'blister copper' (I33). The slag formed in the roasting operation (which contains a considerable amount of copper) is called 'roaster slag' (I33). 6th, the blister copper is melted, any slag which forms removed by skimming, the metal stirred up and subjected to the oxidising action of air, then covered with a thin layer of anthracite, and a pole of green birch or oak kept immersed in it. When the process has been carried far enough, and the metal has arrived at the 'tough pitch,' that is has become soft and malleable, the 'refined copper' (I33) is ladled out into moulds, and is ready for the market. The object of the refining is to remove the impurities in the blister copper, leaving in the refined metal a small proportion of cuprous oxide, without which the copper would not possess the proper degree of toughness. The slag produced in the last operation, and known as refinery slag (I33), is rich in copper. Together with the roaster slag it is treated again in the 4th operation.

A second series of specimens, also from Swansea, illustrates the same process of copper smelting.

In the year 1882-83, nearly 24,000 tons of copper and copper alloys were imported into India.

Cupreous pigments (I33).

Copper enters into the composition of several pigments, which are mostly green. Amongst them are emerald green (I33), an arsenite of copper, and mineral green (I33), containing a carbonate of the same metal. Blue verditer (I33) also consists essentially of a carbonate of copper.

MERCURY.

FOREIGN.

Mercury (I34).

The ore from which nearly all the mercury of commerce is prepared is cinnabar (I34), a sulphide containing 86.2 per cent. of metal when pure. Native mercury (I34) is too rare to be of much consequence. In the preparation of the metal, cinnabar is mixed with lime or smithy-scales, and heated in retorts, when metallic mercury (I34) distils over, leaving sulphide of calcium, or of iron, behind. By another process, the ore is heated in contact with air, and the resulting sulphurous acid and vapour of mercury passed through a series of chambers, in which the latter condenses.

Vermilion (I34).

Vermilion, which has the same composition as cinnabar, is prepared artificially by mixing sulphur and mercury, in the proper proportions, and distilling; the resulting sublimed cinnabar (I34) after being finely ground is known as vermillion (I34); the pigment is also made by a wet process.

SILVER.

INDIAN.

No true ores of silver are worked in India, but the galena in some parts of the country contains a high percentage of the precious metal, 100 oz., and more, to the ton of lead having been found in some samples. The only region where its extraction appears to be a regular industry is the Shan States of Burmah. The lead is

there subjected to a process of cupellation,¹ and the silver obtained used as currency, either in the form of ingots, or made into small hollow beads (I34).

The copper ore of Bairuki,² in the Deogarh district, was found to contain silver, some of which was experimentally extracted; a medal (I34) made of it is included in the collection.

SILVER.

FOREIGN.

Amongst the more important ores of silver are the native metal (I34), pyrargyrite (I34), and stephanite (I34); the last two are sulphantimonites, the former containing 59·8 per cent. of silver, when pure, and the latter 68·5. Cerargyrite (I34), or chloride of silver, contains 75·3 per cent. of metal.³ A considerable amount of silver is obtained from argentiferous galena (I34); the process by which it is extracted from the lead has already been noticed in a previous section.⁴

PLATINUM.

INDIAN.

Platinum occurs in some quantity along with the stream-gold of certain localities in Burmah, and of the Dihing river (I34) in Assam, but the gold-washers in neither province appear to attach much value to it. The Assam platinum is accompanied by iridosmine (I34).

Trifling quantities of platinum have been found in some other parts of India, of which Mánbhum is one, the stream-gold of the Guram river (I34) containing traces of the metal in question.

GOLD.

INDIAN.

Gold is a widely distributed metal in India, being found in the territories under nearly every government

¹ See lead.

² P. 95.

³ A nearly complete series of the ores of silver is included in the systematic collection of minerals. See native silver and amalgam, case 1; argentite, case 3; hessite, stromeyerite, sternbergite, case 4; sylvanite, freieslebenite, pyrargyrite, proustite, case 5; tetrahedrite, stephanite, polybasite, cerargyrite, bromyrite, iodyrite, case 6.

⁴ See foreign lead.

in the Empire. It occurs in quartz-reefs traversing metamorphic and sub-metamorphic rocks, and in some of the ancient schists themselves; some of the newer formations, certain of the Gondwána and tertiary sandstones, for instance, are auriferous, the gold in them having, doubtless, been originally derived from the first-named sources.

It is, however, from alluvial deposits, the gold in which is derived in part direct from the ancient rocks, and in part from the sedimentary formations (being thus doubly derivative), that the native gold-seekers of the present day obtain nearly all the gold they find.

In former times the quartz-reefs of Southern India were mined on a considerable scale, and even now quartz mining is not altogether unknown to the native workers.

Of late years numerous gold-mining companies have been started, under European auspices, to work the quartz-reefs of Southern India.

Malacca (I35).

Some gold is collected in Malacca, which is said to be obtained, in part at least, by washing a soft argillaceous sandstone (I35).

Burmah (I35).

Amongst the gold washings which have attracted the most notice are those at Shwe-gyeng, in Tenasserim, which are known to be of great antiquity. About 20 years ago the daily earnings of the washers were estimated at 5 annas per man. Some Chinese subsequently commenced work, but did not find it sufficiently remunerative to induce them to continue. In 1867 an Australian miner made another attempt, but with a similar result.

Specimens of the auriferous sand (I35) and clay (I35), and of the washed gold (I35), are included in the collection. Small nuggets, or quartz pebbles, containing a large proportion of gold (I35) are sometimes found.¹

Gold has been obtained in several other parts of Tenasserim. Almost all the tributaries of the Tenasserim river contain the precious metal, the little Tenasserim

¹ Other specimens of stream gold from Shwe-gyeng, including a nugget of 88.2 grains, are included in the collection of minerals, case 1.

river (I35) amongst others. Near the town of Tenasserim pits have been sunk in the alluvium and gold (I35) obtained therefrom.

Gold has also been washed in Pegu (I35), and in various localities in Independent Burmah, of which the neighbourhood of Amarapura (I35) is one.

Assam (I35).

Upper Assam has long been noted for its gold (I35),¹ and in former times the Rájás derived a considerable revenue therefrom, a yearly tribute of 4,000 tolahs (about 1,650 ozs.) of gold being exacted from the 'sonwals,' or washers. At times a still larger revenue is said to have been obtained. The original source of the gold is, no doubt, the crystalline rocks which form some, at least, of the higher ranges bordering Upper Assam; some of the gold-bearing streams, however, flow through tertiary rocks only, and in them the metal has a doubly derivative origin. Gold-washing used to be carried on in at least 30 or 40 different streams, but of late years the industry has been in a declining condition, and the amount of gold now obtained appears to be comparatively small. Three samples yielded, on assay, about 90 per cent. each of pure gold.

A fragment of quartz containing gold (I35) is said to have been found in the Bogápani river, in the Khási hills.

Bengal (I35).

Gold-washing is carried on in several parts of Chutia Nágpur, including Mánbhum (I35), Singbhum (I35), Gangpur, Jashpur and Udaipur. The washers do not consider the trade a lucrative one, but the small results they obtain are partly owing to their want of industry; when they have collected enough for a day's subsistence they generally cease work. The operation is conducted in a large curved wooden dish (I35), into which the auriferous sand (I35) and gravel is scraped. "The dish when filled is placed in shallow water, and the operator working with his hands soon separates and throws aside all the coarser gravel and stones, while the agitation of the water serves to carry away all the mud and lighter portions. The dish is then balanced on the palm

¹ See also case I.

of the left hand, and oscillated to and fro with the right ; this serves to throw off the greater portion of the remaining gravel, and the process is completed by a circular motion, which is communicated to the water in the hollow of the dish, by which even the smallest particles of foreign matter are separated, and the final result is a residue of black iron-sand (I35), in which the specks of gold are readily apparent ; but as mercury is not employed in this part of the country, all the very small and invisible gold is lost."¹

It has been ascertained by experiment that the richest gold-bearing alluvial deposits are those on the sub-metamorphic series, while those covering the metamorphic rocks are either barren or comparatively poor in gold. Specimens of washed gold from different localities in Mánbhum (I35) and Singbhum (I35) are included in the collection,² and in the collection of minerald (case 1) is a nugget from Jashpur which originally weighs 222 grains, but from which a piece was cut for assay, so that the present weight is about 200. The nugget contains about 95 per cent. of gold and 5 of silver.

Gold is also washed for in Orissa (I35), and in one or two other parts of Bengal.

Punjab (I35).

Most of the rivers in the Punjab contain auriferous sands, which are washed for gold in many places, mercury being sometimes employed to aid in collection of the precious metal. Amongst other rivers may be mentioned the Indus (I35), the Beas (I35), and its tributary the Párbati (I35). A specimen of quartz, with galena, containing visible gold (I35), has been obtained from the Waziri Rupi, here (the Párbati rises), in Kulu.

Afghánistán (I35).

Gold occurs near Kandahár in quartz veins, which traverse the zone of contact between cretaceous limestone and trap. The veins (I35) vary in thickness from the width of a pencil line to many feet ; the contact rock (I35) is calcareous and slightly cupriferous. Considerable quantities of gold were obtained a few years ago, during the occupation of Kandahár by the British, from a

¹ V. Ball, *Economic Geology*, p, 193.

² See also case 1.

mine about 3 miles north of the town. The larger masses of gold, some of which are said to have been the size of a man's fist (!) were extracted by hand, and the quartz afterwards crushed and treated with mercury. The mine was yielding gold in considerable quantity when it suddenly caved in, burying the miners beneath a mass of débris. No later information concerning the mine is available.

Bombay (I35).

Auriferous quartz-reefs occur in the Dhárwár district of which the most important is the Hatti Katti (I35). Alluvial gold (I35) is washed for in the same district. The auriferous sand is scooped up into a basket, or wooden tray, and carried to an oblong washing-box, across which a piece of elastic stick is jammed at the lower end to form a catch. Water is then ladled on to the wash-dirt, with a scoop (I35), made of a calabash, while the washer kneads it with his left hand and throws out all the larger pebbles. This goes on till a layer of sand has been formed in the box, so thick that the stick at the lower end is no longer a sufficient catch, when a second stick is jammed in and the washing recommenced, until the sand has risen almost level with the second stick; both sticks are then removed, the washer stirs up the sand with a short stout piece of wood, and then sweeps everything into a large wooden tray (I35) held below the lower end by an assistant. The washer then takes the tray, places it in the water, and performs the needful shaking and washing, till nothing remains at the bottom but fine sand, generally of a black color. He then tilts the tray a little, and by judiciously dropping water out of his hand, on to the small layer of sand, drives all the lighter particles forward and leaves the spangles of gold exposed. This small residue is then collected carefully by washing down into a half coconut shell, and taken home to be treated with mercury.¹

Madras (I35).

The existence of gold in Southern India has been known from time immemorial. The Ophir of Solomon, whence were obtained ivory, apes, peacocks and gold, is most generally considered to have been on the West

¹ R. B. Foote, Records, G. S. I., Vol. VII, page 138.

Coast, and some centuries ago immense accumulations of gold are believed to have been in the possession of the ruling princes. The remains of numerous and extensive mines are still visible, some of which have been worked during the present century, while alluvial gold-washing is carried on at the present time. In 1879 public attention was directed to the scheme of working the auriferous reefs of the Wynaad and Kolár. The first company was launched in December of that year; at the end of June 1881, 41 companies were in the field with a nominal capital of £4,400,000.

The sanguine hopes at first entertained were doomed to speedy disappointment; many of the companies have passed into the hands of the liquidator, and the future of others remains yet to be decided. Although up to the present the amount of gold obtained is altogether insignificant in comparison with the capital invested, the opinion is still held by some that gold-mining in Southern India may, under favourable circumstances, and when skilfully and economically conducted, yield a fair profit.

The quartz-reefs of the Wynaad traverse gneissose rocks. They are very numerous, and some of large size. A large proportion of them, at least, are auriferous, but the average amount of gold hitherto found is comparatively small. Locally, indeed, they contain a considerable amount, as may be seen from picked specimens in the collection (I35), which also includes washed gold from Dayvallah (I35) in the same district.

Auriferous quartz (I35) and alluvial deposits (I35) also exist on the coast of Malabar, and at least two companies have conducted mining operations in the quartz reefs of the Nilgiri district (I35).

GOLD.

FOREIGN.

The source from which nearly all the gold of the world is obtained is the native metal. Native gold (I36) is mainly found in veins or reefs of quartz (I36) penetrating metamorphic rocks. Very commonly the quartz contains iron-pyrites (I36) in greater or less proportion. The connection between the occurrence of pyrites and that of gold may probably be traced to the fact that

gold is slightly soluble in a solution of sulphate of iron. In presence of reducing agents, this salt is liable to de-oxidation and alteration to disulphide of iron, or iron pyrites. When this change occurs the gold held in solution is set free and remains entangled in the pyrites (I36). The latter mineral is very prone to alteration into limonite (I36) or hydrous ferric oxide, which again sometimes changes to hematite (I36) or anhydrous ferric oxide. The gold still remains unaltered during these changes. Owing to such alterations of pyrites, auriferous quartz-veins often (although not always) have a rusty appearance at the outcrop.

Arsenical pyrites (I36) is another mineral not uncommonly met with in auriferous quartz veins, and, like the iron pyrites, is in such cases itself auriferous.

Although gold is mainly found in quartz-veins, it sometimes occurs to some extent in the surrounding metamorphic rocks, especially in the wall-rock of the veins. In Brazil, for instance, gold is found in talcose quartz-schist (I36) and quartzite (I36).

By the denudation of the gold-bearing rocks mentioned above, and the transport of the eroded materials to lower levels, auriferous alluvial deposits of gravel (I36) and sand (I36) are formed. During countless ages nature does on a great scale what the gold-washer does on a small one; there is a constant tendency to concentrate the heavy gold, through its greater resistance to the current, while the lighter particles of sand and clay are swept lower down. Hence, virgin auriferous drifts are sometimes found of great richness, far surpassing what could be hoped for in the parent rocks from which the gold was originally derived.

In quartz-mining the rock is first crushed, and the gold afterwards separated by washing and amalgamation. The gold dissolves in the mercury, which is subsequently distilled off, leaving the precious metal behind. The same operations, with exception of the crushing, are gone through in working auriferous alluvial deposits.

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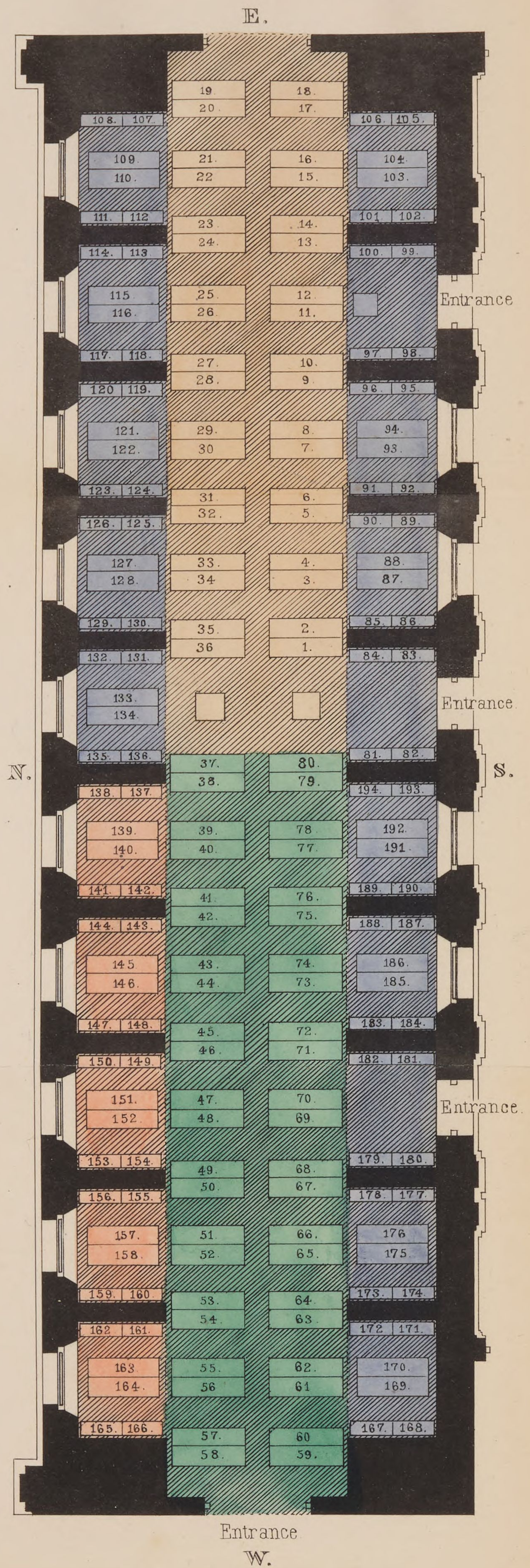
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Mallet, F. R.

Popular Guide to the Geological Collections in the Indian Museum, Calcutta
No. 5 Economic Mineral Products. By F. R. Mallet

Calcutta 1883

Geo.u. 528 hn-1/5

urn:nbn:de:bvb:12-bsb11608085-1